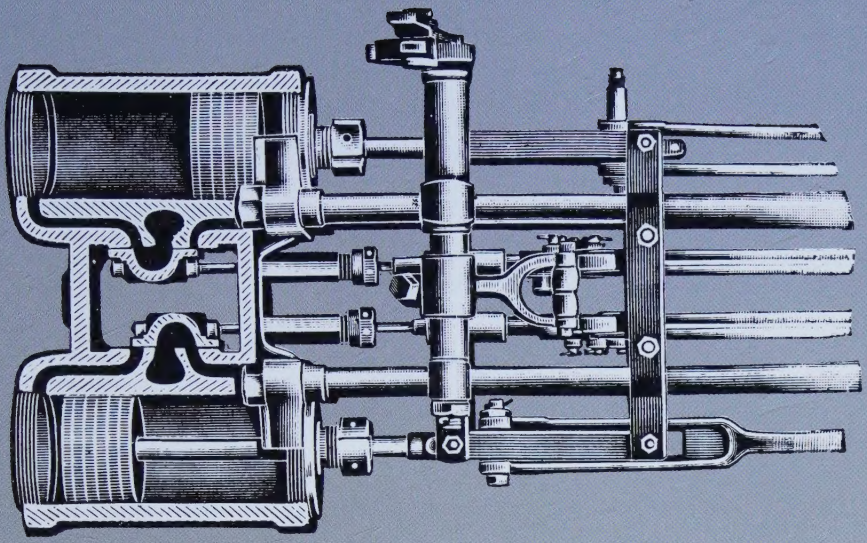

Steam Propelled Vehicles

Chapters 35 through 39 reprinted from
Self-Propelled Vehicles
"A practical treatise on the theory, construction, operation, and management of all forms of automobiles" – 1914

by James E. Homans

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SELF-PROPELLED VEHICLES

A PRACTICAL TREATISE
ON THE
THEORY, CONSTRUCTION, OPERATION, CARE AND MANAGEMENT
OF ALL FORMS OF
AUTOMOBILES

BY

JAMES E. HOMANS, A. M.

WITH UPWARDS OF 500 ILLUSTRATIONS AND DIAGRAMS, GIVING THE ESSENTIAL DETAILS OF CONSTRUCTION AND MANY IMPORTANT POINTS ON THE SUCCESSFUL OPERATION OF THE VARIOUS TYPES OF MOTOR CARRIAGES DRIVEN BY STEAM, GASOLINE AND ELECTRICITY.

THEO. AUDEL & COMPANY
SIXTY-THREE FIFTH AVENUE
NEW YORK
1911

Steam Propelled Vehicles

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Self-Propelled Vehicles
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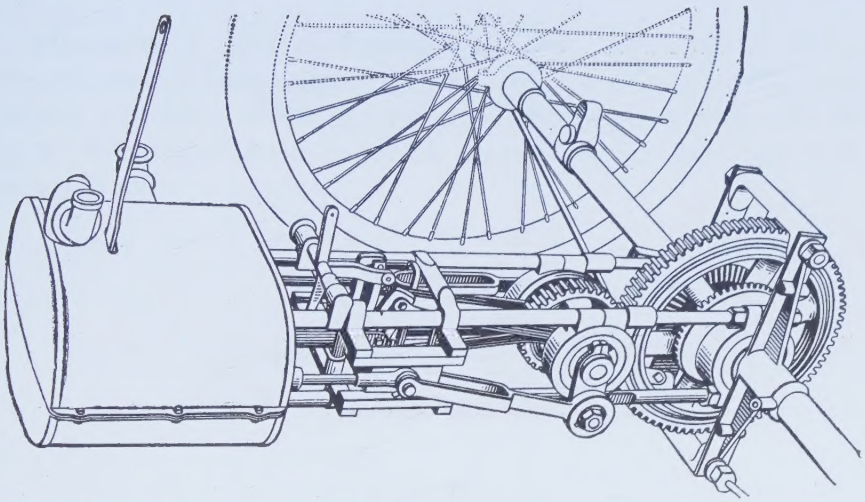


FIG. 32.—Engine and Spur-drive Connections of the Stanley Steam Carriage. The engine is "direct-connected," driving the differential through a spur gear. A vertical strut suspends the engine from the body of the carriage.

CHAPTER THIRTY-FIVE.

THE OPERATION AND CONSTRUCTION OF STEAM ENGINES FOR AUTOMOBILES.

Steam as a Motive Power.—Vehicles propelled by steam possess certain advantages which are conceded, even by the most ardent advocates of the gas engine. There is a combination of good features inherent in steam propulsion that has met with much favor.

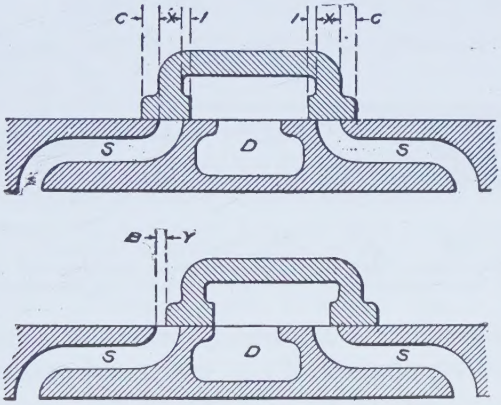


FIG. 332.—Diagrams illustrating the "Lap" and "Lead" of a Steam Cylinder Slide Valve. In both sections, S and S are the steam ports, and D the exhaust. The upper section illustrates the "laps" of a valve; the space between the lines C and X giving the "outside lap," and between the lines X and I the "inside lap." The lower section illustrates the "lead" of a valve; the space between lines B and Y showing the opening of the valve at the beginning of the right-hand stroke.

It is possible with steam to have ample power together with great overload capacity without an extremely heavy plant.

The steam car as manufactured in America is not a copy of foreign ideas, and for some work it has never been approached by any other form of motive power. In hill climbing and speed it is supreme, and the silence in operation and freedom from vibration make it very desirable when maximum comfort in touring is desired.

Among its chief advantages are *flexibility* and *ease of control*. A steam car may be operated at any speed from zero to maximum. All variations of speed can be obtained without gear shifting, as it can be easily varied by changing the amounts of steam admitted to the engine. The engine of

a steam car can never be stalled on account of the absence of dead centres and non-power strokes, the reserve force in the boiler and the ability of such a prime mover to stand an overload of over 100 per cent. This enables one to obtain the maximum power output under extraordinary conditions. A two cylinder steam engine produces a torque which can only be equaled by an eight cylinder, four cycle, or a four cylinder, two cycle gas engine. Because of this uniform application of energy, the wear on tires is reduced to a minimum, and the elasticity of the steam and freedom from shock and vibration, reduces considerably wear and tear on the entire mechanism.

The improved methods of boiler construction, permit the use of steam of high pressures and of considerable degree of superheat, both of which tend to decrease the fuel consumption. Either gasoline or kerosene may be used for fuel. The regulation of the fire and feed water is controlled by automatic devices, hence, the attention of the driver is not diverted from the steering wheel and throttle.

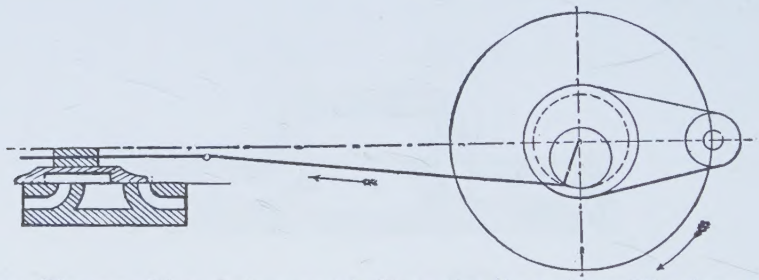


FIG. 333.—Diagram with a single eccentric, illustrating the position of the steam valve, when the crank pin is at the return dead centre, the throw of the eccentric being at an angle off the perpendicular. The arrows show the direction of motion.

The Slide Valves of a Steam Cylinder.—The mechanism by which steam is admitted to the cylinder of a steam engine, consists of a sliding valve of such a shape as to open communication from one end of the cylinder to the exhaust, while the other end of the cylinder is receiving steam direct from the steam chest. This will be readily understood from the accompanying illustration. There are two kinds of valves in common use on steam carriage engines; the common D-valve shown herewith, and the piston valve, as shown in a number of engines hereafter to be described. The object obtained by both valves is the same, although the piston valve is preferred by many engineers because it is better balanced in its operation, and also because, owing to its packing rings, it is less liable to leakage. However, with a well-made valve of either variety, the ends of economy and durability are equally maintained.

The Operation of the Slide Valve.—The valve controlling the inlet and exhaust ports of a steam cylinder is made of such length that, when in mid-position, it completely closes both inlet ports, neither admitting steam nor allowing it to be exhausted. In the valve shown on the accompanying sectional cut, it is evident that, supposing it to be moved either to the right or to the left, the communication will be opened with the exhaust port on the one side, sooner than with the steam chest on the other, thus permitting with a very slight variation in the length of the stroke, that the exhaust remain open even while the inlet of the steam to the opposite face of the piston is cut off. In calculating the proportions of cylinder valves there are two important items to be considered—the "lap" and the "lead" of the valves. The "lead" of a valve is the amount by which the steam port is open when the piston is at the beginning of the stroke.

The lead may be changed by varying the angular advance of the eccentric. The "lap" of a valve indicates any portion added to the length of the valve, so as to increase the portion of the stroke during which the ports are covered, beyond that length which is positively required to insure the closing of all ports when the valve is in mid-position. There are two kinds of "lap." The "outside lap" is any portion added to the length of the valve beyond that necessary to cover both inlet ports at mid-position. The "inside lap" is any portion added to the hollow or inside portion of the D-valve, over and above what is necessary in order to cover the inner edges of the steam ports, and to close the exhaust port from both sides when the valve is in mid-position. The exhaust valve is closed somewhat before the completion of the stroke, thus allowing the residual steam in the clearance to be compressed somewhat before the opening of the inlet. The most important result obtained in this manner is that the compression produces a temperature, as near as possible, the same as that of the incoming steam, which is an efficient factor in heat economy, although producing some back pressure that slightly reduces the *mean effective pressure.*

From the operations of this valve and cylinder, it must be evident that its stroke cannot be equal to that of the piston in the main cylinder. It cannot, therefore, be operated direct from the crank-shaft of the engine. Accordingly, the most usual method of operating the steam valves of an engine is by an eccentric on the main shaft, which operates the valve rod. This device may be either a single or double eccentric, according to the requirements.

The Eccentric Gear and Link Motion.—An eccentric is a circular piece of metal, a wheel in fact, except for the fact that instead of turning upon its centre, it is attached to the shaft at

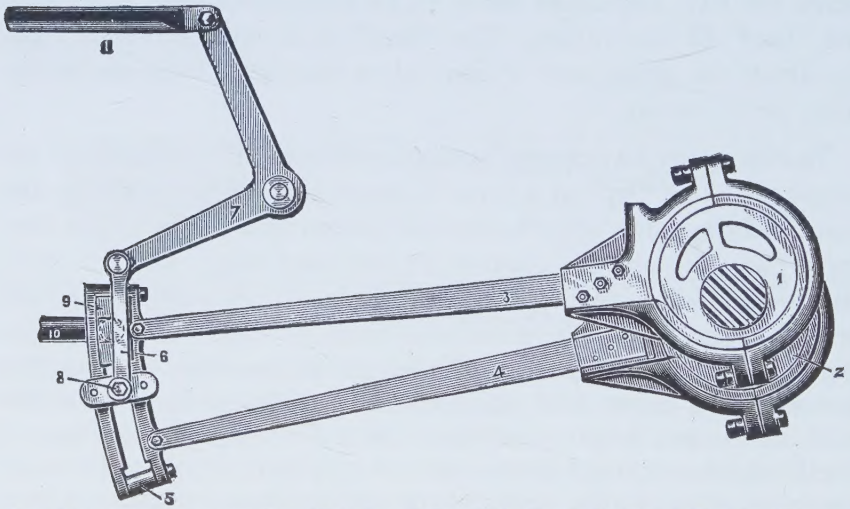


FIG. 334.—Diagram of the Link Motion and Eccentric Gear of a Steam Engine. The parts shown are: (1) backward eccentric; (2) forward eccentric; (3-4) eccentric rods; (5) slotted shifting link; (6) link hanger; (7) reversing arm; (8) link saddle pin; (9) link block; (10) valve stem; (11) reach rod. The position shown in the cut indicates that the backward eccentric is in gear which gives a reverse motion to the engine.

a point near its periphery. Around this disc-shaped piece is attached a circular metal strap, joined to a rod, which may be either attached direct to the valve rod, or, where two eccentrics are used, to one end of the swinging link. The link is an arc-shaped metal piece, usually made with a slot through the greater part of its length. It is hung from its centre point to a link-saddle, which, as shown in the accompanying figure, is bolted to either side of the slot and is suspended from the link hanger

either above or below. Within the slot is set a link block, as it is called, so that it may slide in the slot through its entire length, whenever the link is raised or lowered on its hanger. To this link block is attached the valve rod. The general arrangements of the link motion may be understood from the accompanying illustration.

The Operation of the Shifting Link.—As already stated, the link motion was originally intended only for reversing the engine, which is to say to enable the steam to be cut off from

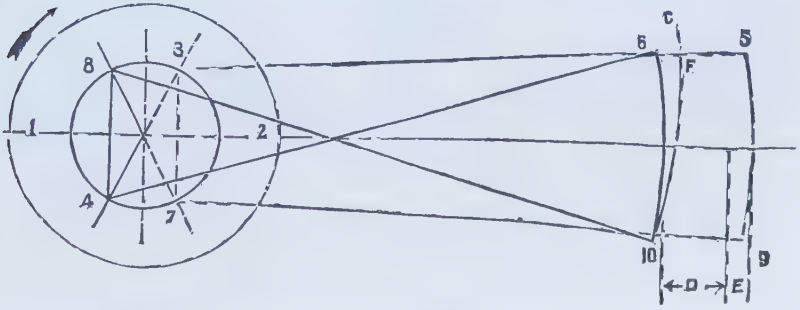


FIG. 335.—Diagram of the Operation of the Link Motion. The centres of the two eccentrics being at 4 and 8, the crank pin at 2, the link at mid-gear, the eccentric rods will be indicated by the full lines, 4-6, 8-10. When the crank pin is at 1, the centres of the eccentrics will be at 3 and 7, and the positions of the rods on the dotted lines, 3-5 and 7-9. The distance, D, indicates the vertical distance between the centres of the eccentrics in the full and dotted-line positions. If from the centre, 8, with the rod as the radius, an arc be drawn to F, the distance, C, shows the position of the link if both rods were "open" with the crank at the cylinder end, 2, instead of at the opposite dead centre, 1. The distance, C, is equal to the distance, E, and the total distance (D + E) that the valve moves is twice the lap, plus twice the lead, plus the distance, or angularity, occasioned by the rods being crossed, when the crank is on the cylinder end dead centre, 2, becoming opened when the crank is at dead centre, 1.

one side of the cylinder and admitted to the other, whenever desired, by shifting the motion of the slide valve. In addition to this function, however, the link motion provides a means for using the steam expansively, when cutting off the supply of live steam at any earlier point in the piston stroke, which act is accomplished by reducing the travel of the slide valve. When the link block is at one end of the slot, the valve receives the motion of the eccentric rod attached to that end of the link, and, consequently, since the links are set at angles somewhat greater than 180 degrees, the one is for the forward motion of the en-

gine, the other for the reversed motion. In the accompanying illustration, the backward eccentric is in gear. By this means, whenever the link is shifted, only the eccentric whose rod stands opposite the link-block imparts its motion to the valve. The other is practically inactive, except for imparting a slight oscillatory motion to the link, which in general practice is negligible. The link which is in gear acts, in reality, like a short-throw crank, or as if it were a single eccentric. From the position of "full-gear"—that is, when the link-block stands at either end of the slot—the travel of the valve may be more or less modified until the centre point of the slot is reached, which point is called

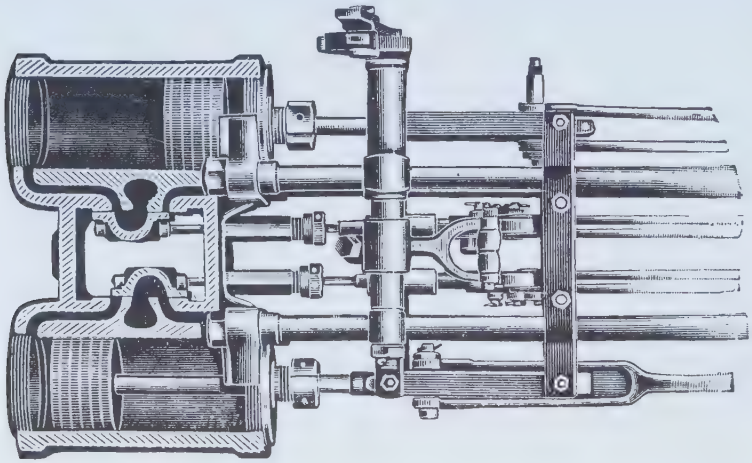


FIG. 336.—View of the Stanley engine with cylinders cut away, to show piston and valve motion. In the position shown, one valve is beginning to open to admit steam to the cylinder; the other valve has passed the point of cut off, the opposite cylinder end being in communication with the exhaust passage. The valves of the Stanley engine are operated by the familiar Stevenson link motion.

mid-gear. There the travel in either direction is so slight that the steam and exhaust ports of the cylinder are not opened. This is in reality the "dead point," and further shifting of the link in the same direction begins the process of reversing by increasing the travel of the valve in the opposite direction. When at mid-gear the valve partakes of the motion of both eccentrics equally, but since their motions describe a cassinian, or flattened figure 8, laid on its side, of which the link-block is the centre, the motion is at its point.

When the link is at full gear, the travel of the **valve equals** the throw of the eccentric, less the angularity of the eccentric rod. When the link is at mid-gear, the travel of the valve is equal to twice the lap and lead of the valve, plus twice the angularity of the eccentric rods. By the angularity of the

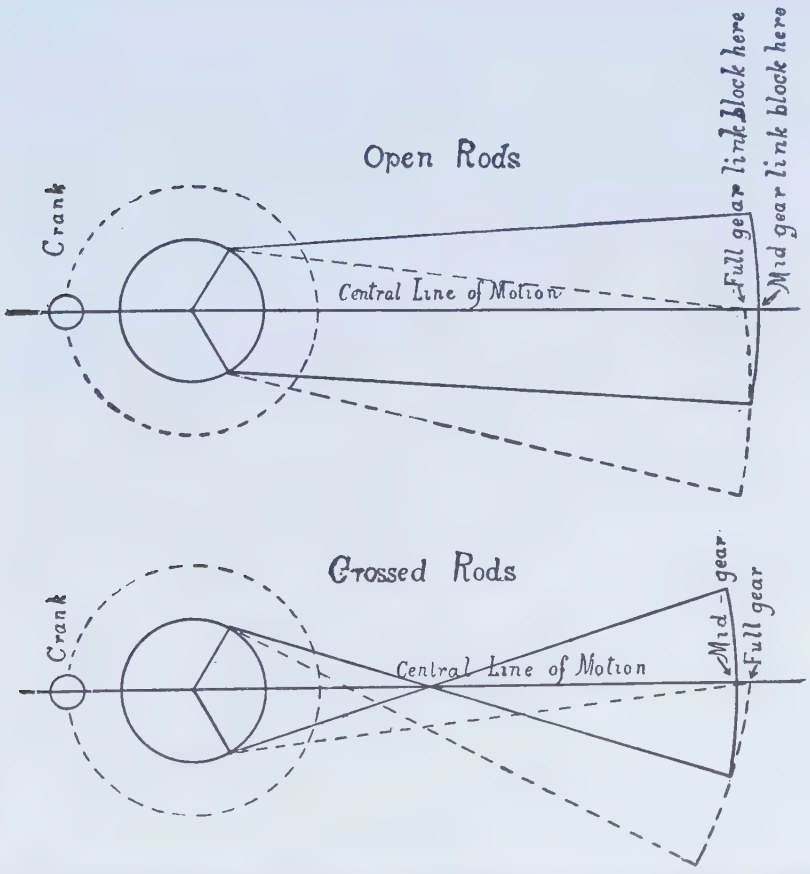


FIG. 337.–Diagram showing the positions of the eccentric throws and rods at full gear and mid-gear, when the rods are "open" and "crossed" with the crank at the forward dead centre, marked 1 in the previous cut.

eccentric rods is meant the distance the centre of the link or the valve would move, should the rod of the geared eccentric be disconnected from it and connected with the other link. The amount of the angularity thus, of course, varies with the length of the rods. The shorter the rods, the greater the travel of the

valve, owing to the crossing of the rods during a one-half revolution of the crank. When the eccentric rods of a direct connected link motion are disposed as shown in the accompanying diagram, and the link motion and gear of the crank is at the

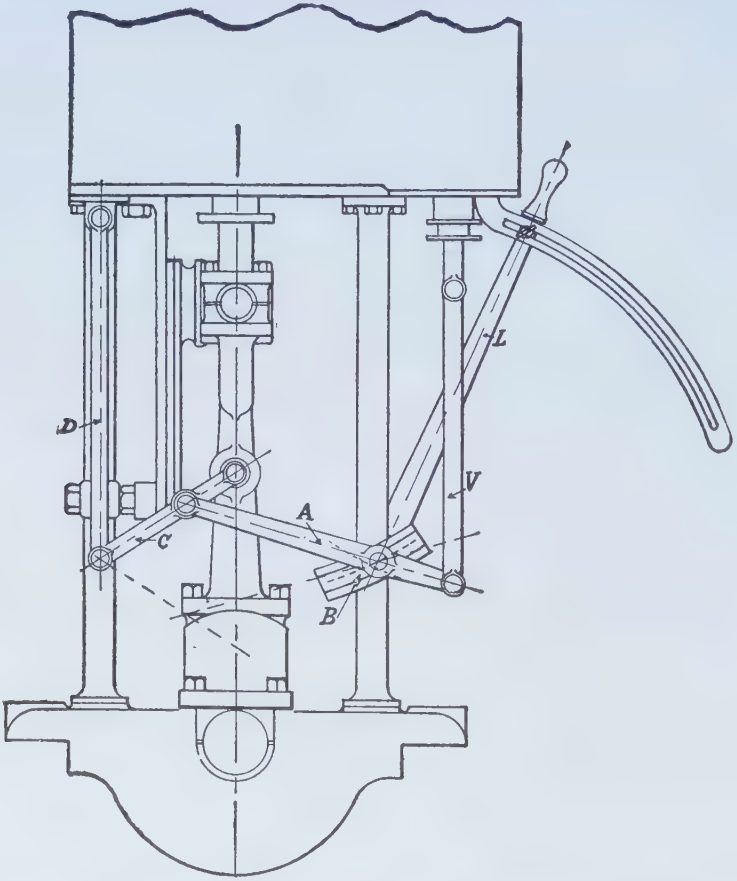


FIG. 338.—Diagram illustrating the principles of the Joy valve gear. Motion is communicated to the valve by a system of levers operated by the connecting rod. The advantages secured by the use of the Joy valve gear are, quick admission and cut off, and constant lead for all degrees of expansion.

dead point marked 1, the rods are said to be open. If they are disposed as shown by the dotted lines in the same figure, and the crank is at the dead point, 2, they are said to be crossed. Open rods give an increasing lead from full gear towards mid-gear, while crossed rods, give a decreasing lead.

The Joy Valve Gear.—This form of valve gear derives its motion from an arm attached to the connecting rod near the wrist pin. The link is pivoted at its upper end and by moving it forward or backward from the central position, the cut off can be regulated.

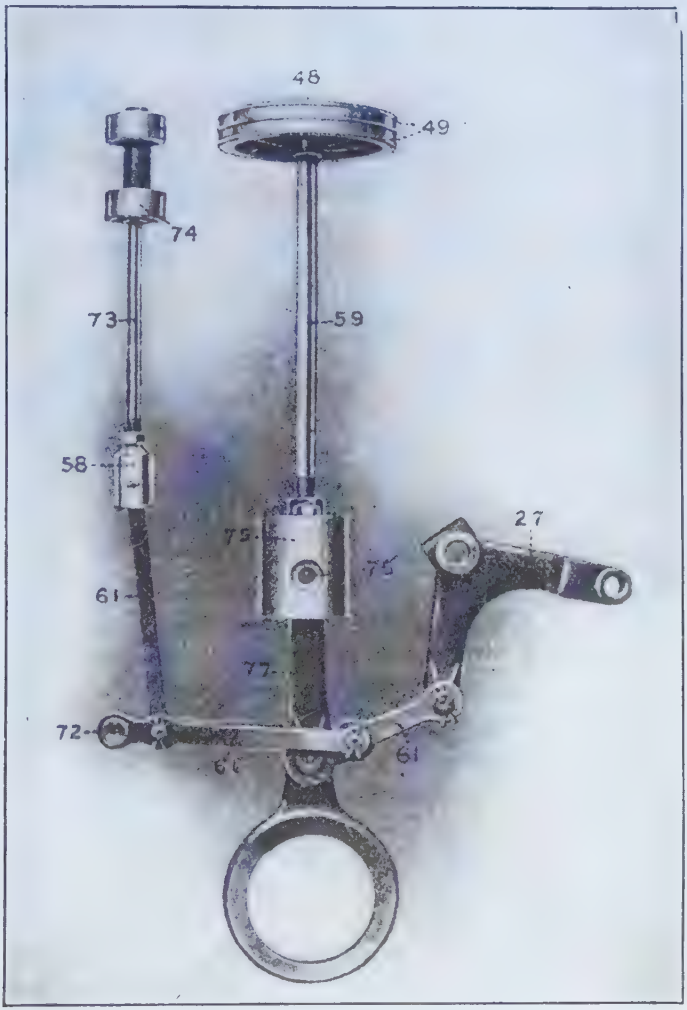


FIG. 339.—The Joy Valve gear as applied to the White engine. The valve gear parts are: 74, valve; 73, valve stem; 58, valve crosshead; 61, valve gear levers; 72, valve slide rollers. The other details shown are: 48, piston; 59, piston rod; 75, crosshead; 76, wrist pin; 77, connecting rod; 27, lever for operating the pumps.

This type of valve gear, is shown in the diagram fig. 338.

The valve rod *V* is operated by the lever *A*. There is a block *B*, provided with a curved slot is used, in which the pin forming the fulcrum of the lever *A* slides.

The motion is imparted to the lever *A* directly from the connecting rod by means of the connecting link *C*, one end of which is pivoted to the connecting rod, the other end to the suspension link *D*.

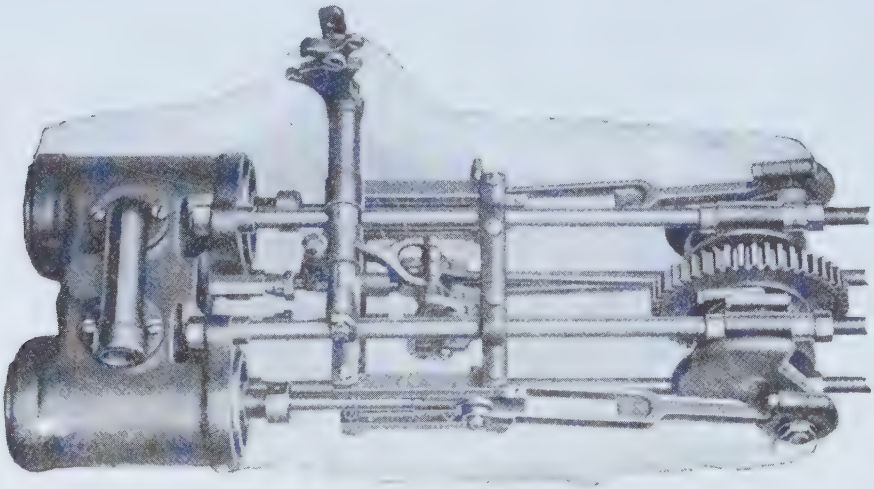


FIG. 340.—View of the Stanley engine, showing main bearing, spur gear, eccentrics, link motion and "hooking up" device. These engines are made in three sizes: 3 x 4; 4 x 5; and 4½ x 6½. The horsepower rating for the several sizes is ten, twenty, and thirty, respectively.

The vertical motion of the connecting link moves the valve an amount equal to its lap and lead, while the horizontal motion causes the ports to open their full opening, by moving the fulcrum up and down in the inclined slot.

By means of the reversing lever *L*, the incline of the block *B* can be altered, or reversed, to reverse the engine.

The diagram fig. 338 is intended simply to illustrate the principle of the valve gear, the engine shown being of the marine type. The Joy valve gear has been adopted by the White Company and its application to the White engine is shown in figs. 339 and 347.

A feature of this valve gear is that it gives a rapid motion to the valve when opening and closing, thus producing a quick admission and cut off. It gives a constant lead for different cut offs, and a compression more nearly constant than that produced with the Stevenson link motion.

The Joy gear while having many good features has numerous joints which are subject to wear.

The Serpollet Single-Acting Engines.—In the effort to simplify, as far as possible, the construction and operation of steam vehicle motors, intended for use on light carriages, several inventors have contrived excellent types of single-acting engines. Among the advantages to be derived from the use of this type of motor, we may mention dispensing with the stuffing-box and several other constructions, which involves constant danger of wear and difficulty or repair. The Serpollet steam engine very much resembles some types of gasoline motors used on heavy vehicles, both as regards the cylinder and piston and operation of the valves. The cylinders are horizontal, of the double opposed type.

The piston is of the trunk type, consisting of a somewhat elongated hollow cylinder, with the crank rod pivoted on the gudgeon pin somewhat less than midway in its length. The valves in this engine are of the familiar mushroom or poppet type, and are opened by a push rod positively operated from a cam shaft. This shaft is operated by a spur-wheel, which meshes with another spur of the same diameter, mounted on the crank-shaft, so that the two turn in even rotation. The exhaust valves are of precisely similar construction and are also positively operated from the same cam-shaft.

Such an engine as this has been constructed with from two to six cylinders, and as may be understood, gives about the same power effect as an engine of the ordinary design and same proportions of stroke, having from one to three cylinders. The cylinders operate on one plane, and are not offset, as in many opposed-cylinder gasoline motors. The steam and exhaust valves are positively operated by a series of cams on a shaft, so that when the steam valve of one is open, its exhaust is closed, in-

volving that the steam valve of the opposite cylinder is closed and its exhaust open. In order therefore to reverse the engine, it is necessary only to slide the row of cams on the square camshaft that carries them, so as to shift the positions and operation of the valves on the two cylinders.

The Piston of a Steam Engine.—The piston of a steam engine, as shown in an accompanying figure, usually consists of a flattened cylindrical piece of slightly smaller diameter than the bore of the cylinder, in which it slides. Steam-tight contact is obtained by springing packing rings into grooves cut in its circumference. The accompanying cut shows three such rings sprung on the piston. The steam admitted through the inlet valve bears upon one face of the piston, and by its expansive energy causes the piston to move.

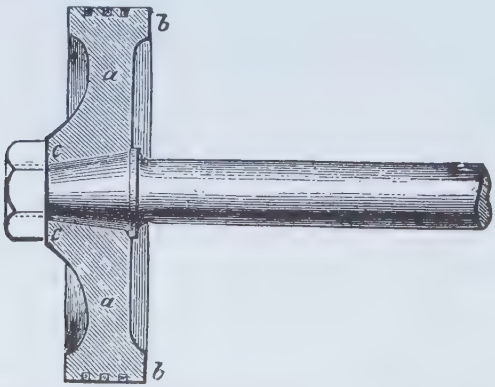


FIG. 341.—The Piston of a small double-acting steam engine, showing method of connecting the piston rod, and the position of the packing rings. The parts are: *a*, *a*, the body of the piston; *b*, *b*, the circumference bearing the packing rings; *c*, *c*, the central boss receiving the coned end of the rod.

The Practical Expansion Ratio for Steam.—In the practical operation of the steam engine, as most generally understood, the steam is fed direct from the boiler to the cylinder, there expanding from its original pressure to a number of volumes, proportioned to the length of the stroke and point of cut-off. The idea of cutting off the supply of steam before the completion of the stroke, and making use of its expansive energy during the remaining portion, constitutes, as we have seen, the first improvement made by Watt. According to Boyle's Law, already quoted, the pressure of the steam is in exactly inverse ratio to

its expansion, which is to say that when a body of steam is expanded to twice its original volume, it should have just one-half its original pressure, so long as the temperature be constant. This law is never exactly followed in practice, the general rule, as shown by indicator diagrams, being a rapid fall during the first period of expansion and a more gradual one in the latter

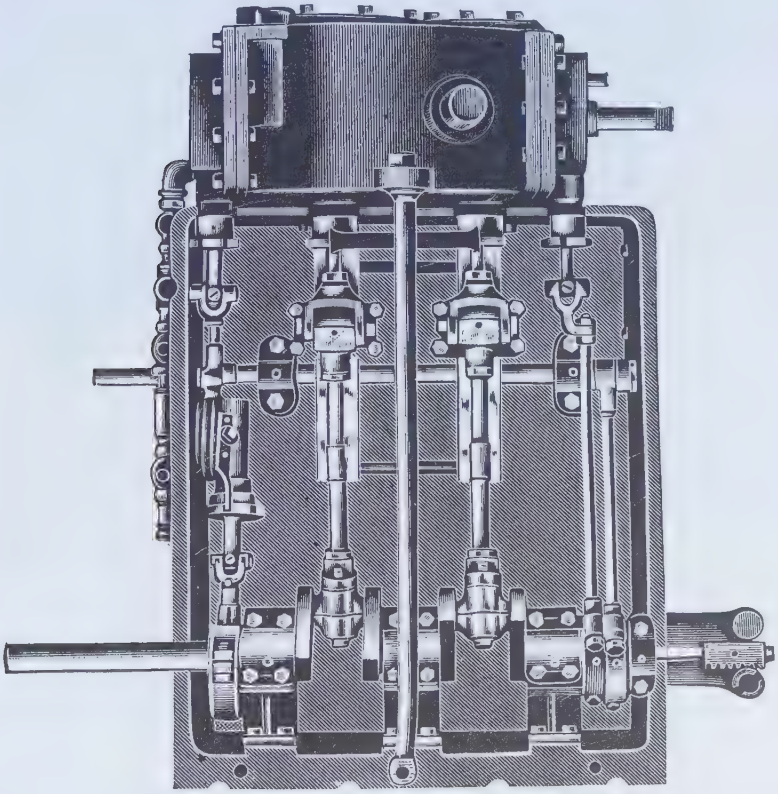


FIG. 342.—The Ofeldt compound engine. The cylinders are cast in one piece and are bolted to one end of the oil box. They are 2½ and 4, with four-inch stroke, and the valve chests are located at each side. The steam enters the H. P. valve chest through a ½ inch connection in the center of the valve chest cover, and exhausts around the cylinders to the L. P. valve chest. The steam exhausts through a ¾ inch connection at corner of valve chest on end of cylinder. The reverse motion is of the special type, only one eccentric being required for each valve. The reverse is set at the end of the crank shaft and extends out through the side of the oil box, where it is connected to a small gear wheel. In either the forward or backward motion the reverse is held in place by the crank shaft. The engine can be reversed when in motion without closing the throttle. Feed water pump is provided operated by an eccentric on the shaft. A simpling connection for starting is made on top of the H. P. cylinder. The valves are the sliding or D type. The engine runs in oil and is rated at fifteen horsepower, a larger size 3½ and 6½ by 5 is rated at thirty horsepower.

period. However, for general purposes, the law is assumed to be perfectly operative, and the rule for calculating the pressure at any point of expansion, is to divide the original absolute pressure by the number of times it has expanded. Thus, steam fed to a cylinder at 100 pounds gauge, or 115 pounds absolute, has a pressure of 57½ pounds when expanded to two volumes, a pressure of 38 1-3 pounds when expanded to three volumes and a pressure of 28¾ pounds when expanded to four volumes.

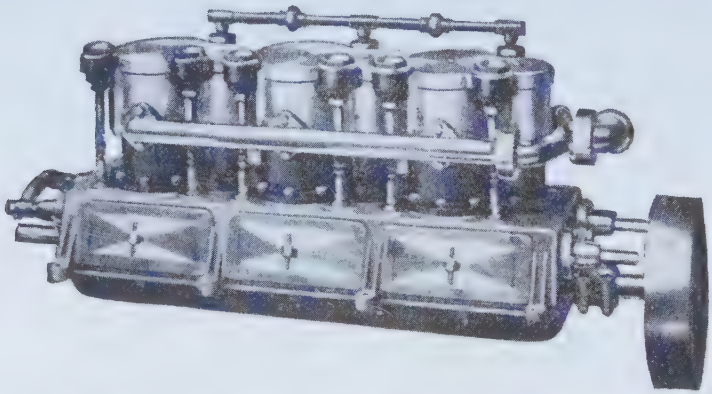


FIG. 343.—The MacLachlan single acting compound steam engine. It has six cylinders, three 3" high pressure and three 6" low pressure with 3½" stroke and is rated at 30 H. P. with 300 lbs. steam and 600 revolutions. The valves are of the poppet type and the valve gear is such that steam may be cut off at any point of the stroke down to three-fourths. One lever controls the entire operation—simpling, compounding, reversing, starting and the variable cut off.

The following table gives the theoretical efficiency of steam cut off at various other points of the stroke:

Cutting off at	$\frac{1}{10}$	stroke	increases	efficiency	3.3	times.
" "	$\frac{1}{8}$	"	"	"	3.07	"
" "	$\frac{2}{10}$	"	"	"	2.6	"
" "	$\frac{1}{4}$	"	"	"	2.39	"
" "	$\frac{3}{10}$	"	"	"	2.2	"
" "	$\frac{3}{8}$	"	"	"	1.98	"
" "	$\frac{4}{10}$	"	"	"	1.92	"
" "	$\frac{1}{2}$	"	"	"	1.69	"
" "	$\frac{6}{10}$	"	"	"	1.51	"
" "	$\frac{5}{8}$	"	"	"	1.47	"
" "	$\frac{7}{10}$	"	"	"	1.35	"
" "	$\frac{3}{4}$	"	"	"	1.29	"

In the steam engine, these values are considerably reduced on account of losses due to radiation, condensation, leakage, etc. In horse power calculations, therefore, the theoretical mean effective pressure is multiplied by a coefficient or *diagram factor* as it is called which varies for different classes of engines from .6 to .9 as has been determined by numerous tests.

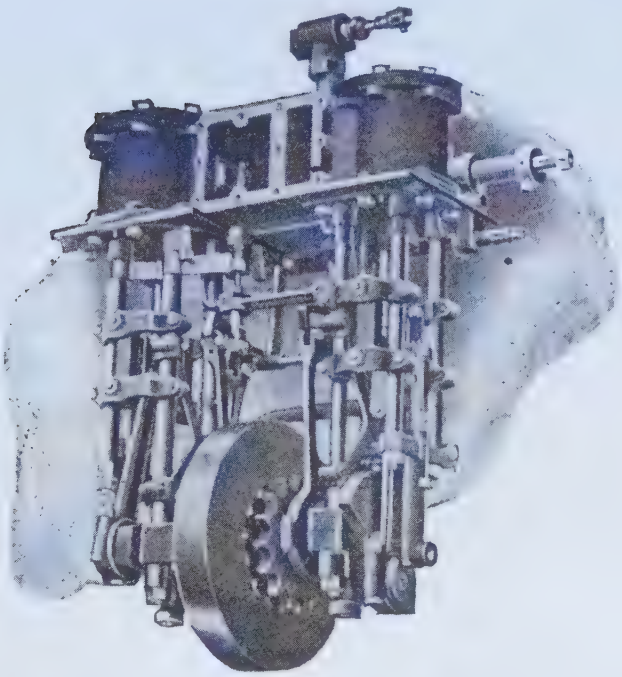


FIG. 344.—The Lane engine. This is a cross compound with steam chests adjacent to each other. Both cylinders have slide valves and the pistons are provided with two snap rings each. The valve gear consists of the Stevenson link motion. The Lane engine is built in two sizes: 3¼ and 5¼ by 3½; 3⅞ and 6¼ by 4. They are rated at twenty and thirty horsepower, respectively.

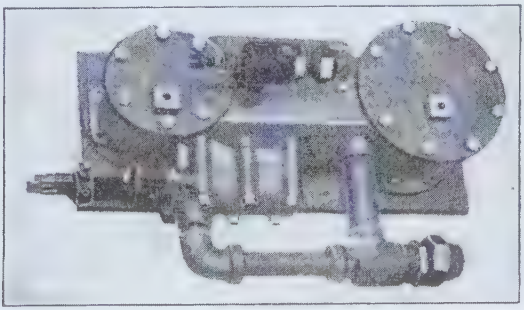


FIG. 345.—Showing simpling valve on back of the Lane engine. It consists of a small cylinder having ports connecting directly with the high pressure exhaust, the high and low pressure steam chests, and the free exhaust. There is a one-piece plug valve having proper passages through it, and arranged so that the different rotative positions effect the changes of ports for converting the engine from compound (using steam first in small, and afterward in the large cylinder) to single expansion (using high pressure directly in both cylinders).

On Compounding a Steam Engine.—A compound engine is one in which the steam is used several times over in as many separate cylinders, although usually applied to engines operating with two cylinders. The steam is fed from the boiler direct to the first cylinder, in which it is cut off early in stroke, in order that its expansion may be utilized to the greatest possible extent. The exhaust from this cylinder is then fed into the second cylinder, generally two or three times the cubic contents of the first, and is worked expansively to a point as near atmospheric pressure as possible. The most practical and efficient application of this

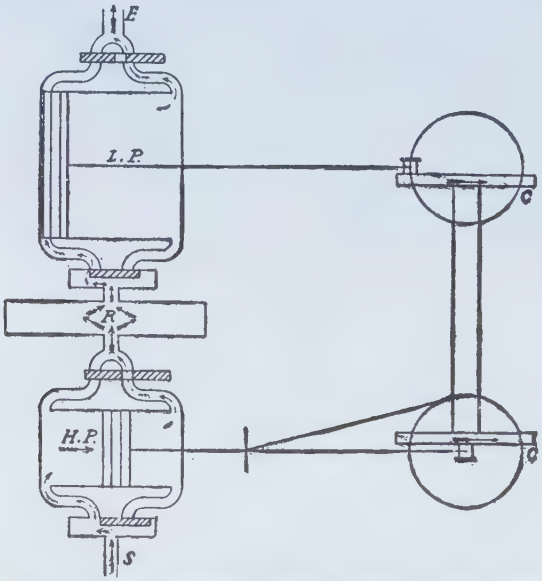
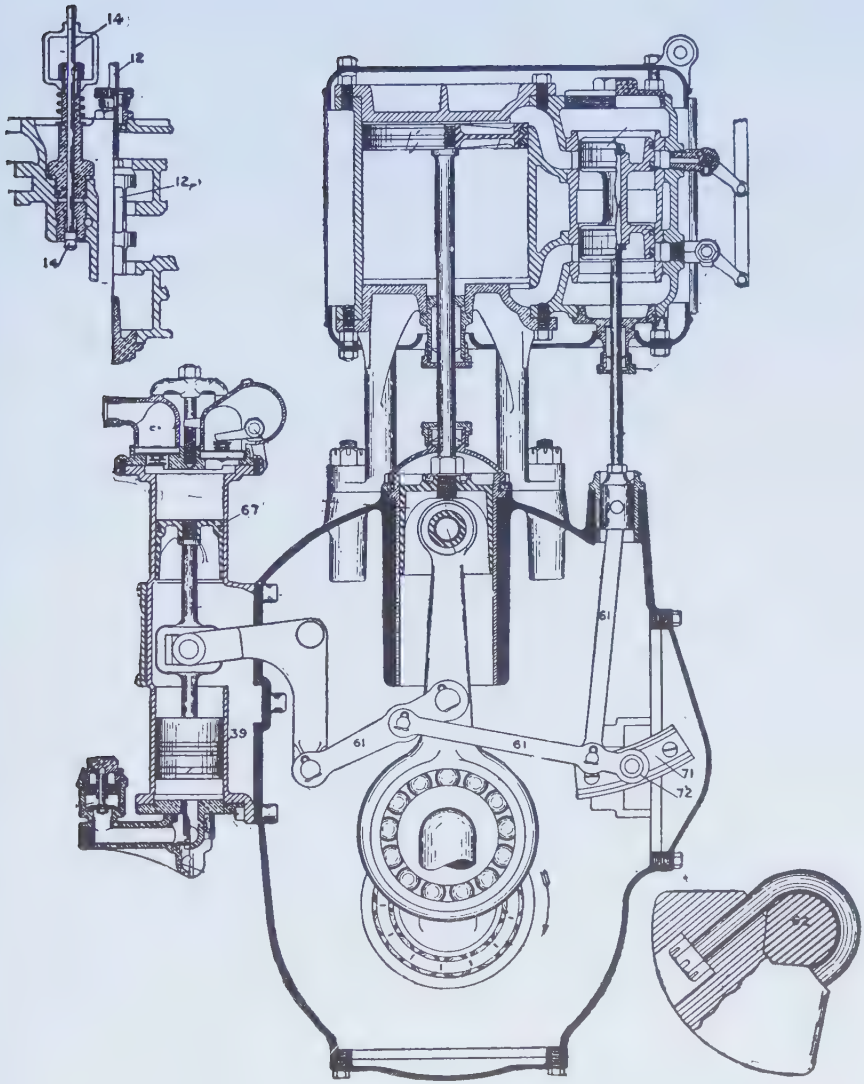


FIG. 346.—Diagram of a "Cross Compound" Steam Engine. The cranks, C and C, are at 90°. The high-pressure steam port is at S; the H. P. exhaust to L. P. cylinder at R, and the exhaust to atmosphere from the low-pressure cylinder, at E.

principle is in the triple and quadruple expansion engines, so largely used in marine work, which, in connection with the vacuum-producing condenser, allows the steam to be worked from the highest available pressure down to near zero. There are two common forms of compound engines of two or three cylinders, which from the arrangements of the working parts, are known as "tandem-compound" and cross-compound." In the tandem-compound engine, the cylinders are placed end to end, the two pistons operating one piston rod. In the



FIGS. 347 and 348.—The White Engine and sectional view of "simpling valves." The engine is a double acting compound fitted with the Joy valve gear (61, 71 and 72), and is built in two sizes: 2½ and 4¼ by 3, also 3 and 5 by 4½. The power rating is twenty and forty horsepower respectively. The simpling valves (12 and 14) are used in starting to admit live steam to the low pressure cylinder in case the high pressure piston be on the dead centre. There are two pumps operated by the engine, an air pump 67, and the condenser pump 39.

cross-compound engine the cylinders are placed side by side, the two piston rods operating on a single crank-shaft. The latter model is that most frequently used in compounding steam engines for motor vehicles.

Compound Steam Engines for Light Carriages.—Although many of the earliest types of the American steam carriage still use simple engines, several of the most excellent of the later patterns have adopted compound engines. The principal objection made by many authorities to the use of compound engines on steam road carriages of light weight is that with cylinders of average dimensions, working pressure of between 150 and 200 pounds, in the high pressure cylinder, and a cut-off generally between $\frac{1}{2}$ and $\frac{3}{4}$ stroke, which has been found most economical under ordinary conditions, the low pressure cylinder would be doing little or no work, the whole strain of operation coming on the former, which would practically be working against a vacuum.

A maker of steam carriage engines states, that in order to obtain effective work from both cylinders of a compound engine, the high pressure cylinder must be made about one-half the size of the cylinder used in the simple engine. Then, he asserts, the mean pressure will range from 75 to 100 pounds in the usual running, with cut-off at $\frac{3}{4}$ stroke and the diameters of the two cylinders in ratio of 1 to 3, and the low pressure cylinder will do its share of the work, with the desired economy of power. The difficulty claimed with this arrangement is, that the total reserve power will then be only about one-half that of the simple engine, unless boiler steam can be admitted to both cylinders at any desired time while running, as well as in starting, and the back-pressure be eliminated by exhausting from both to atmosphere.

The higher boiler pressures, made available through improved construction is very favorable to the use of compound engines, permitting a greater expansion range and more economical working.

CHAPTER THIRTY-SIX.

BOILERS AND FLASH GENERATORS.

Small Shell Boilers for Carriages.—Many of the best known makes of American steam carriage have vertical fire tube shell boilers. All such boilers are of small dimensions, with a consequently small water capacity. But they have a very extensive heating surface, owing to the insertion of a large number of fire

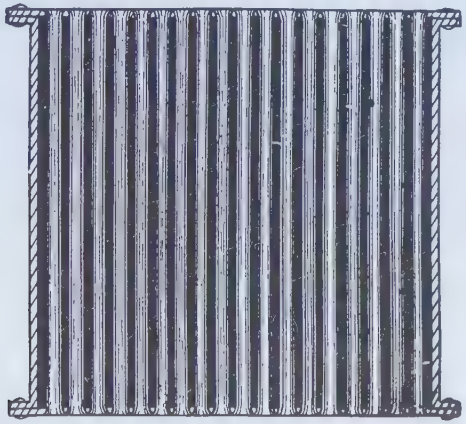


FIG. 349.—Shell Boiler, with flange connections for the tube plates. The shell is strengthened by winding several layers of steel piano wire around the length of the boiler. This cut gives a section on the centre, showing one row of tubes. These are usually made of copper which possesses a superior heat conducting property.

tubes and, according to many showings, seem capable of generating a power pressure far in excess of the usual rule of proportions for surface.

The shells are constructed of seamless steel, formed up or drawn out of solid pieces of the best quality of metal, and by the same method used in making tanks for soda fountains, oxygen-gas outfits, carbon-dioxide machines, etc., many of which are tested up to 3,000, 4,000 and 5,000 pounds per square inch. A wall section of steel made in that way three-sixteenths of an inch

thick and having the form of a cylinder twenty inches in diameter, withstands a pressure of more than fifteen hundred pounds per square inch.

In order to get a large heating surface in a shell of small diameter, the tubes are placed very close together and there are a great number of them as shown in fig. 350, hence, the boiler heads are strengthened in such a way that they are even stronger than the shell.

FIG. 350.—The Stanley fire tube boiler. The shell and lower head are of one piece of pressed steel. The bands, as shown in the cut are of thin brass, to hold the asbestos covering in place.

It is claimed by a well-known builder of automobile boilers that it is impossible to explode a boiler as constructed for an automobile, since according to their tests, the tubes will flatten at a pressure of ten hundred pounds and then leak gradually until the pressure falls, without doing other damage.

The fire tube boiler used in the Stanley car has a shell slightly different from the ordinary construction. It is of the same type

as originally used on the Locomobile Steamers and is shown in fig. 350. The shell which is of seamless pressed steel, is reinforced by two layers of piano wire wound around its exterior under tension. The lower head is part of the pressed steel shell. The tubes are 33/64 inch outside diameter and are expanded into the heads by means of a taper expander, shown in fig. 351. All tubes are 14 inches long, excepting those in the 26 inch boilers which are 16 inches long. In the 18 inch boilers there are 469 tubes with 66 square feet of heating surface. In the 23 inch boilers there are 751 tubes with 104 square feet of heating surface. In the 26 inch boilers there are 999 tubes with 158 square feet of heating surface.

FIG. 351.—Roller tube expander for expanding tubes of boilers and burners. In expanding a tube, the roller end is inserted in the tube and the central tapered pin turned with an inward pressure. The action of the pin presses the rollers against the tube with great force, thus expanding the latter and making a tight joint.

As usually constructed, the tubes in shell boilers are spaced the same distance apart, the distance betwen the outside edges of the tubes being only one-quarter of an inch. It will be seen from the dimensions of the Stanley boilers given above, that a large heating surface is obtained with small diameter of shell. Since the tubes are quite short, the entire heating surface is in close proximity to the fire and hence very effective.

Of Tubular Boilers in General.—The wide use of tubular boilers in steam carriages and for other purposes is explained by the fact that in its use the problem of how best to control the circulation, to the ends of quick steaming and higher durability, through more uniform distribution of heat, has been best solved. Although very many varieties of tubular boiler possess

high efficiency as generators of steam, none of them attain such great power for absorbing heat but what there is still room for efforts to discover some means of neutralizing waste in this particular.

Small boilers with seamless drawn shells for automobiles are now manufactured in a number of sizes, the standard dimensions and horse power ratings are as follows:

AUTOMOBILE BOILERS.

(Seamless Shells.)

Internal Diam. In.	Thickness of Shells In.	Number of ½ inch Tubes.	Length of Tubes In.	Actual Horse Power.	Approximate Weight in Pounds.
14	3/16	309	13¼	4 4/10	112
16	3/16	420	13¼	5 2/10	146
16	¼	420	13¼	5 2/10	154
17	3/16	480	13¼	6 8/10	158
17	¼	480	13¼	6 8/10	174
18	3/16	529	13¼	7 5/10	180
18	¼	529	13¼	7 5/10	196
19	3/16	586	13¼	8 2/10	203
19	¼	586	13¼	8 2/10	222
20	3/16	676	13¼	10 1/10	231
20	¼	676	13¼	10 1/10	257
20	¼	676	14¼	11 2/10	272
20	¼	676	15¼	12 1/10	287
20	¼	676	16¼	13	302
23	¼	850	13¼	12	293
23	¼	850	14¼	13	312
23	¼	850	15¼	14	331
23	¼	850	16¼	14 9/10	350

The sixteen, seventeen, eighteen and nineteen-inch boilers listed above are made with tubes fourteen, fifteen, sixteen seventeen and eighteen inches long, which approximately increases the horse power in proportion as the tubes increase in length.

Heavy Truck Boilers.—Fire tube boilers suitable for commercial vehicles differ from the automobile type, only in that both heads are riveted in, and that the shell is made from heavier stock. The shells are not seamless drawn, but are welded by an electrical process making them homogenous and uniform throughout. Truck boilers are usually made with an extended shell which projects a few inches below the crown sheet to form a casing for the burner. It is, therefore, necessary to cut holes

through the side of the shell to accommodate mixing tubes and other burner pipes. Heavy truck boilers with welded shells are regularly manufactured in various sizes as follows:

HEAVY TRUCK BOILERS.

(Welded Shells.)

Internal Diam. In.	Thickness of Shells In.	Number of $\frac{1}{2}$ inch Tubes.	Length of Tubes In.	Actual Horse Power.	Approximate Weight in Pounds.
22	$\frac{5}{16}$	825	$13\frac{1}{4}$	$11\frac{6}{10}$	332
22	$\frac{5}{16}$	825	16	$14\frac{4}{10}$	354
22	$\frac{5}{16}$	825	20	$17\frac{9}{10}$	390
23	$\frac{5}{16}$	850	18	$16\frac{6}{10}$	384
23	$\frac{5}{16}$	850	22	$19\frac{6}{10}$	420
23	$\frac{5}{16}$	850	23	$20\frac{5}{10}$	464
24	$\frac{5}{16}$	951	13	$13\frac{5}{10}$	365
24	$\frac{5}{16}$	951	16	$16\frac{6}{10}$	433
24	$\frac{5}{16}$	951	18	$18\frac{7}{10}$	472
24	$\frac{5}{16}$	951	20	$20\frac{8}{10}$	525
24	$\frac{5}{16}$	951	22	$22\frac{9}{10}$	566
24	$\frac{5}{16}$	951	23	$23\frac{9}{10}$	590
24	$\frac{5}{16}$	951	24	$24\frac{9}{10}$	608
24	$\frac{5}{16}$	951	26	28	659
24	$\frac{5}{16}$	951	28	29	700
24	$\frac{5}{16}$	951	30	$31\frac{1}{10}$	742
28	$\frac{5}{16}$	1320	16	23	675
28	$\frac{5}{16}$	1320	20	$28\frac{4}{10}$	844
30	$\frac{5}{16}$	1470	16	$25\frac{1}{10}$	850
30	$\frac{5}{16}$	1470	20	$32\frac{2}{10}$	890

Boiler Tubes.—In the construction of shell boilers the tubes are made, either of steel plated with copper or zinc, or of seamless drawn copper.

In boiler construction, copper is superior to steel from the fact that it has a much higher thermal conductivity, involving considerably smaller loss of heat in proportion to its exposed surface.

The relative heat conducting power of copper and steel is such that one square foot of copper heating surface is as efficient as 2.13 square feet of steel heating surface. The choice of steel or copper tubes, therefore will depend in part on the boiler efficiency desired.

The working pressure to be carried, also governs the choice between copper and steel for tubes. Copper more easily resists the chemical action of impure water.

Advantages of Controlling Circulation.—By providing suitable arrangements for directing the rising and falling currents, so that interference is obviated, a very desirable end is attained—chemical impurities, held in solution by the water, and precipitated so as to form scale deposits, when it is evaporated, are prevented from locating and hardening; being received into mud drums suitably arranged at the lowest point of the water chamber, where they can be conveniently removed.

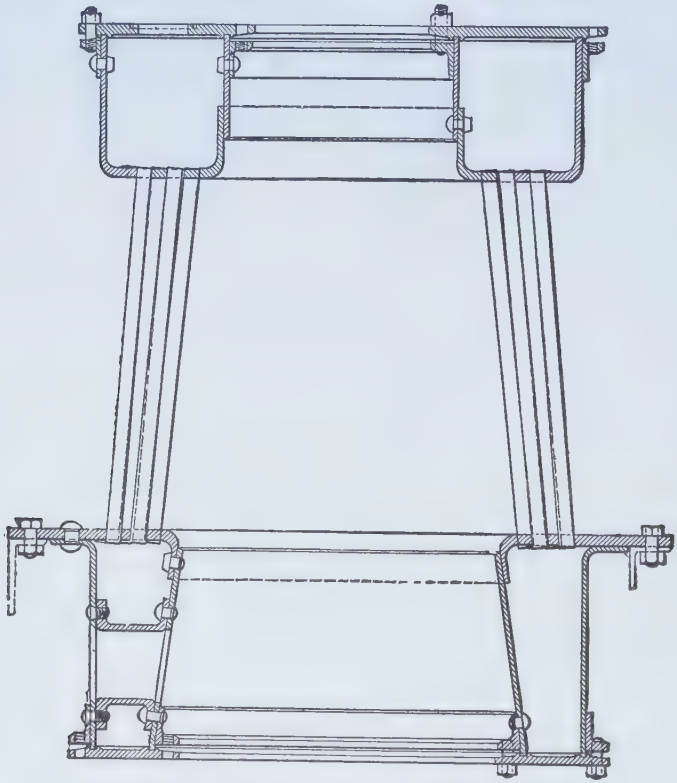


FIG. 352.—The Thornycroft Steam Wagon Boiler.

According to statistics furnished by various authorities these scale deposits, consisting mostly of lime and other non-conducting substances, interfere with the heat-conducting properties of the metal to an enormous extent. A deposit of 1-16 inch involving a loss of 13 per cent. of the fuel; a deposit of ⅛ inch, a loss of 25 per cent.; a deposit of ¼ inch, a loss of 38 per cent.; a deposit of ½ inch, a loss of 60 per cent. The result of allowing such incrustations to increase will be inevitably that the metal surface exposed to the fire is burned out and the boiler ruined.

Water Tube Boilers.—A water tube boiler, consists essentially of, 1, a drum in which is contained both the water and steam. In construction this drum may be either vertical or horizontal. A vertical drum is sometimes spoken of as a *stand pipe*. In sizes suitable for automobiles, the drum is from about five to eight inches in diameter.

In addition to the drum there is, 2, a series of pipes or coils. In the case of a vertical drum, one end of each coil is connected to the lower end of the drum and the other end of the coil, to the upper part of the drum. These coils or pipes are called the *upflow* coils or *risers,* because the circulation of the water through them is upward.

The reason for this is that water expands as its temperature increases, and consequently, its weight per unit volume is diminished. Hence, the water in the drum being of lower temperature than that in the coils, has a greater density and therefore causes the water to rise in the coils.

In water tube boilers having horizontal drums, a *down flow pipe* is necessary. The upper ends of the coils are connected to the drum usually at the water level. A separate pipe, 3, called the *down flow pipe* is attached to the end of the drum at its lowest point, the other end being connected with the lower end of all the coils. The circulation, due to the varying density of the water is, 1, from the drum, 2, through the down flow pipe, 3, to the coils, and 4, back to the drum which it enters as a mixture of steam and water.

The upflow coils are of small diameter while the down flow pipe is much larger. For the proper flow of the water, the cross sectional area of the down flow pipe should be equal to the sum of all the cross sectional areas of the coils, as must be evident.

Advantages of Water Tube Boilers.—With the water tube boiler, the fact that the full force of the steam pressure cannot bear on any one extended surface involves that in the event of

overheating or sinking of the water level, only one or two of the tubes may burst with no very serious consequences.

In the ideal water tube boiler, however, the tubes would run across the draught through a portion of their length, at least, thus making possible a greater absorption of heat, through the breaking of the air currents. This result is immensely increased when the successive rows of tubes are staggered, so as to still further divide up the draught currents.

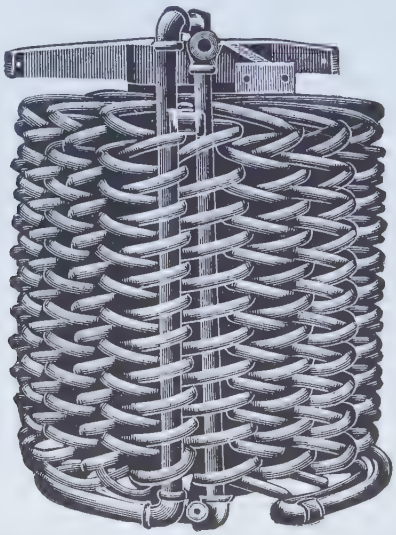


FIG. 353.—The Ofeldt water tube boiler (automobile type). It consists of a central verticle drum, surrounded by a number of pipe coils which are connected to the drum at its extremities. The drum holds a reserve of water, which, when the boiler is in operation, circulates through the coils absorbing heat from the fire, and re-entering the drum at the top as water and steam. The amount of water in the drum varies from three gallons in the smallest size to eight gallons in the 24-inch boiler. Steam is taken from the top of the drum and passed through a superheater before delivery to engine.

The Ofeldt Water Tube Boilers.—These boilers are built with both horizontal and vertical drums. The vertical drum type is most in use for automobiles while those with horizontal drums are adapted to marine use.

As shown in fig. 353, the first mentioned type consists of a central drum made of standard boiler pipe, the same height as the boiler and five inches or more in diameter, according to the size of the boiler. It has a half inch bottom securely welded.

The stand pipe is covered with a steel cap, on which extend three arms to the boiler cover, holding the boiler proper in the casing. The cap is

threaded and securely fitted to the stand pipe. The reserve of water in the stand pipe and coils varies from three gallons in the smallest size to eight gallons in the twenty-four inch size boiler.

The coils are made of one-eighth iron pipe in the small sized boiler, and a combination of one-eighth and one-quarter pipe in the larger sizes. They are coiled at a pitch of 1 1-4 inches to give the proper circulation and prevent the pipes from being clogged. These coils are attached to the stand pipe at the top and bottom with right and left connections.

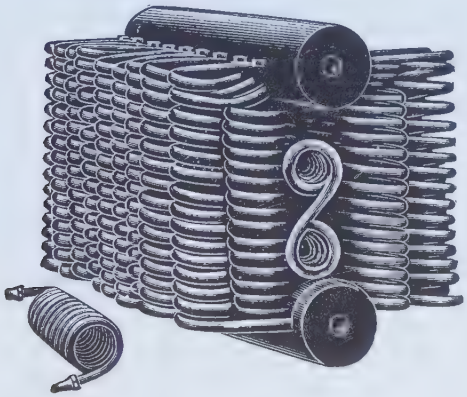


FIG. 354.—The Ofeldt water tube boiler (marine type). This boiler consists of two horizontal drums connected on each side by numerous vertical *up flow* coils. Between the two series of coils are a set of *down flow* coils connected to the two drums. The cooler water in the upper drum flows down through these coils to the lower drum, thence up through the up flow coils absorbing heat from the fire and re-entering the upper drum as steam and water.

The standard dimensions of the vertical drum type as manufactured are as follows:

Size	Height	Weight	H. P.
15½ inches	17½ inches	145 pounds	4 to 6
16 "	17½ "	145 "	4 " 6
18 "	18 "	165 "	6 " 8
20 "	20 "	210 "	8 " 10
22 "	21 "	300 "	10 " 12
24 "	21 "	345 "	12 " 15
28 "	24 "	525 "	20
32 "	30 "	1000 "	30
36 "	42 "	1500 "	40

These boilers, as listed according to the builders, are rated when used in connection with a single or double, double acting high pressure engine, operating under 250 pounds steam pressure, turning 400 revolutions per minute and *without* vacuum.

When used in connection with compound engines they will give half as much again as the listed ratings, and for marine use in connection with triple expansion engines they will give just double the high pressure rating. Thus the 28-inch boiler 24 inches high is 20 H. P. with a double acting, high pressure engine; with a compound, 30 H. P. and with a triple expansion, 40 H. P. If the boilers are made higher than listed—within a reasonable limit—it will increase the H. P. from one to three for every six inches added to height. The steaming capacity of a boiler also depends upon the fuel. These ratings are made with kerosene as fuel.

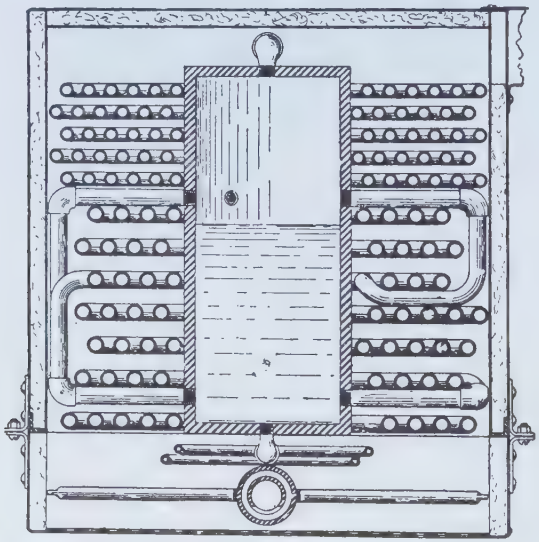


FIG. 355.—The Walker semi-flash steam generator. It consists of a central vertical drum surrounded by pipe coils. The feed water enters the top coil and flows down to the fifth coil, raising its temperature to near the boiling point. From the fifth coil it flows into the bottom of the central drum, thence into six flash steam generating coils and back to the steam space of the drum. From the top of the drum steam is drawn off and carried down to the lowest coil and superheated before delivery to the engine.

Semi-flash Boilers.—Boilers of this type are a combination of the shell and flash boiler. The volume of water carried in the shell gives considerable reserve power, hence, the boiler does not become inoperative in case of a temporary derangement of the feed pump. Two examples of semi-flash boilers are shown in figs. 355 and 357.

The Walker Semi-flash Boiler.—This boiler is provided with a non-tubular shell around which is placed a number of coils of pipe as shown in fig. 355. The five coils at the top are called the *water pre-heating coils.*

Cold water from the feed pump enters the topmost coil and flows down coil by coil, until it reaches the fifth coil.

At this point the water is raised almost to the boiling point. These five coils, thus form a feed water heater. The water passes from the fifth or lowermost of the pre-heating coils into the bottom of the central drum.

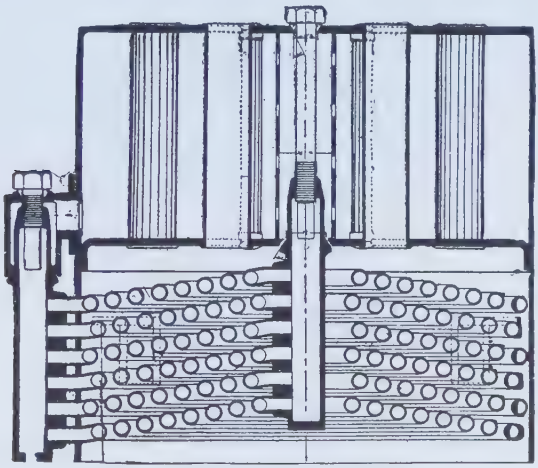


FIG. 356.—The Geneva Carriage Boiler. This boiler consists of several coils of tubing connected at inner and outer extremities to headers, as shown. The water and steam chamber above is constructed like an ordinary flue boiler.

From this central drum, the water, already at the boiling point, is delivered into six flash steam generating coils. These six coils are placed one below the other, directly beneath the five water pre-heating coils above referred to. Each of these flash steam generating coils is independently connected to the central stand-pipe. In shape, these coils are volute. The outer terminal of each of these coils is connected to the bottom of the central drum below the water level, while the inner terminal is carried up and connected to the drum at a point above the level to which the water in the central drum ever rises. By this plan, the hot water which the pre-heating coils deliver into the central drum, is forced to rapidly circulate through these coils and is flashed into steam, which is collected in the top of the central drum.

From the top of the central drum, the steam is drawn off and carried down to the very bottom of the generator and passed through a superheating coil located directly in the fire where the steam is dried and superheated, that is, raised to a temperature higher than that corresponding to its pressure.

The Lane Semi-flash Boiler.—This boiler, shown in fig. 357, consists of one continuous set of coils, superposed on a tubular shell. Connection between the coils and shell includes a *separator*.

The feed water, which enters the uppermost coil, is first heated by the spent gases that are too cool to effectively heat the hotter parts of the boiler below.

The water passes continuously from the upper coil through each succeeding one below, and as it is heated, comes into contact with still hotter surfaces in progressing (as in a flash boiler) till it issues from the bottom coil as steam and water into the centrifugal separator at the side.

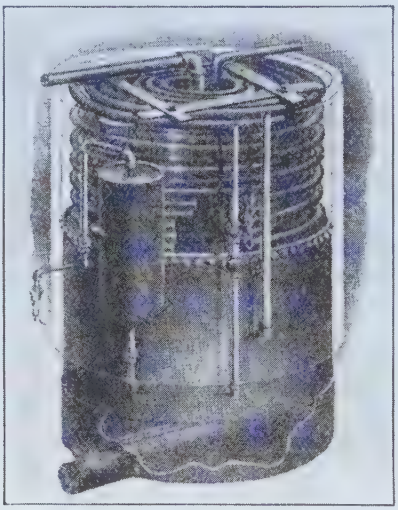


FIG. 357.—The Lane boiler. The feed water enters at the top of the coil and passes continuously from the upper coil through each succeeding one below, coming in contact with still hotter surfaces as it progresses (as in a flash boiler) till it issues from the bottom coil as steam and water into the centrifugal separator at the side. From the top of the separator the steam that has been generated in the coil passes to the upper part of the shell boiler, located beneath the coil, and the water by gravity to the lower part. Steam is drawn from the top head of the shell boiler.

From the top of the separator the steam that has been generated in the coil passes to the upper part of the shell boiler, located beneath the coil, and the water by gravity to the lower part. Steam is drawn from the top head of the shell boiler.

The coils being somewhat removed from the most intense heat are made of brass, a metal that conducts the heat through it more readily than steel.

The shell portion is of pressed steel with lower head and side walls of one piece and seamless. The tubes are one inch in diameter and welded to the lower head.

Serpollet's Flash Boilers.—The first real impulse to the modern steam carriage was the invention by Léon Serpollet in 1889 of the famous "instantaneous generator," known by his name. It consisted of a coil of one and one-half inch lap-welded steel tubing flattened until the bore was of "almost capillary width"—this he later increased to about one-eighth inch—and this, surrounded by a cast-iron covering to protect the steel from corrosion by heat, was exposed to the fire. The result was an extremely rapid generation of steam, the coil being first heated, and the water being vaporized almost as soon as it was injected into the tube.

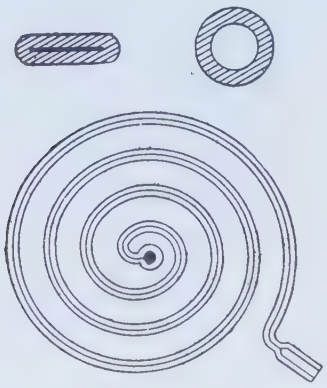


FIG. 358.

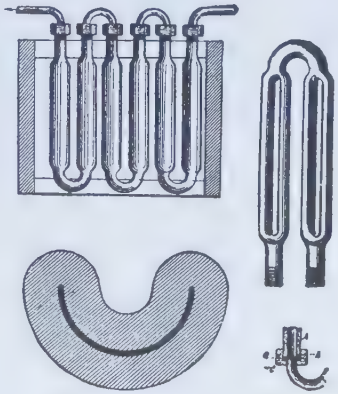


FIG. 359.

FIG. 358.—Earliest Form of the Serpollet Flash Generator; a coil of flattened steel tubing.

FIG. 359.—Second Form of the Serpollet Flash Generator: a series of tubes pressed as shown, bent U-shape and nested; the extremities being connected by joints and bent unions.

Later, he improved the efficiency of his coil by corrugating its surface. With such a generator of 108 square inches of heating surface more than one boiler horse power could be developed, the average hourly evaporation being forty pounds of water.

The usual working pressure was 300 pounds to the square inch, but each tube could bear a test as high as 1,500 pounds.

One great advantage lay in the fact that the high velocity required by the steam and water in the narrow tube served to keep the surface thoroughly free from sediment and incrustations. For vehicles requiring an additional generative power two such coils were used, one above the other, the water being injected into the lower and the upper one serving to superheat the steam.

To stop the engine it was necessary only to shut off the water feed pump, with the result of stopping the generation of steam at once.

In improved boilers of the Serpollet type a number of straight tubes were united by bent joints and nested, the several layers being connected in series. Moreover, each tube length was flattened, so as to form a U-shape, or crescent, in its cross-section, which arrangement greatly increased its evaporating capacity. But the most efficient form was reached in the design shown in Fig. 361, which shows three superposed sections of tubing; the lowest, four tiers of coil; the second, six tiers of "zig-zag," the successive tiers being staggered, as shown; the third, several tiers of flattened tube twisted to angles of about forty-five degrees.

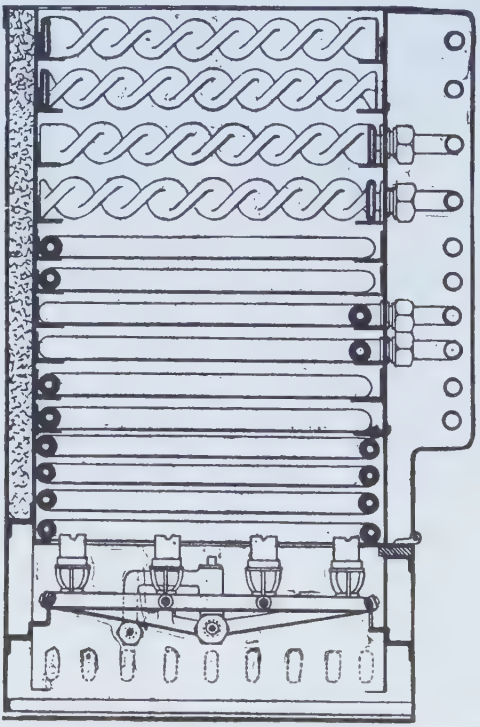


FIG. 360.—Later Form of the Serpollet Flash Generator, consisting of three layers of tubing. The four lowest tiers shown form a coil into which the feed water is injected; the second series of six tiers are arranged "zig-zag," like the nested tubes shown in Fig. 344; the third, or topmost, series of four tiers are also arranged "zig-zag," but are flattened and then twisted as shown.

The water is fed to the lowest section, which is immediately exposed to the fire, being thence passed to the second, whose available heating surface is of the greatest possible dimensions, and finally delivered, as superheated steam, from the uppermost twisted coils. The several sections of tubing are connected together *in series* by bends and unions outside the case, as shown, and the entire generator is enclosed in a double sheet-iron casing packed with asbestos. By the arrangement of the tubing, as here shown, the full power of the heater, in both draught

and radiated heat, is utilized, as in the type of boiler shown in Fig. 361, but the circulation of the water is perfectly under control and rapid generation of steam assured.

For a six-horse power boiler of this type the outside dimensions, including heater space, are about 2½ x 1½ feet, the total tube length, ninety-five feet, and the heating surface, about twenty-five square feet; giving a generator of convenient size for a four-seat road carriage.

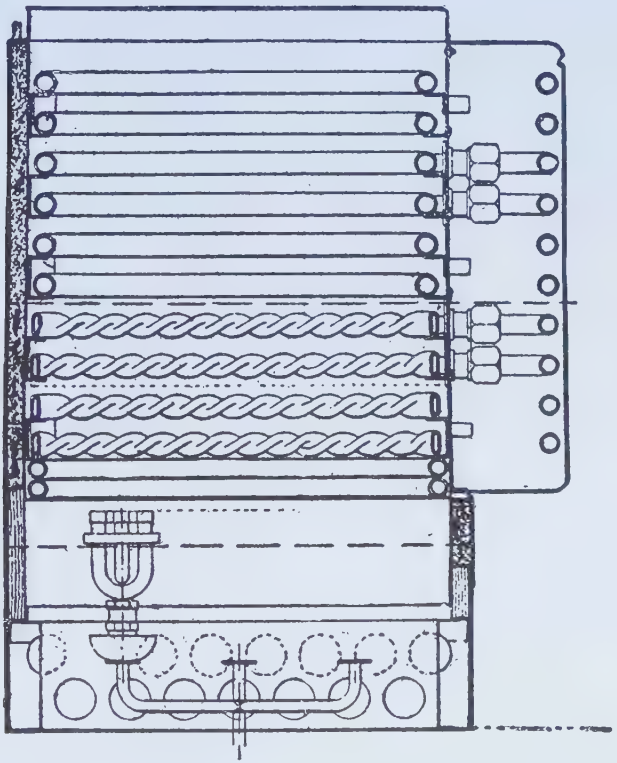


FIG. 361.—Recent Form of the Serpollet Flash Generator. In this type the twisted tubes are placed at the bottom and the "zig-zag" nested tubes at the top. The reason for this arrangement is that twisting the tubes affords a much larger heating surface; hence these tubes are directly exposed to the fire.

Of Flash Generators in General.—Following along the lines of Serpollet's famous "flash" generator, with its numerous advantages in point of quick steam, high pressure capacity, freedom from scale deposits, and complete immunity from explosion, several designers of steam carriages and wagons have produced improved "boilers" of similar description.

Serpollet's first generator, as applied to his light steam carriage of 1889, was merely a coil of flattened tubing.

Later two such coils, connected in series, formed his generator, and finally the complicated trains of coils and bent tubing.

In the latest generators described the water is fed to the lowest tier of tubing, and the steam is taken off at the top, as in the several types of coiled water tube boilers, already described.

The contrary procedure is followed in most of the really successful flash generators produced by other inventors. The Blaxton generator feeds from the lowest water coil, but the Simpson-Bodman, White Automobile Manufacturing Co., and others feed from the top and superheat the steam in the lowest coils.

This seems to be the more logical process for this type of generator, since, as the water is explosively vaporized by contact with the heated tubes, it follows that the progress should be from the lowest to the highest temperature, vaporizing and superheating the steam, rather than allowing it to follow a course from higher to lower temperature, with the accompanying consequence of loss of heat. By making the tubes of sufficient capacity to vaporize a good quantity of water, surprisingly high temperatures may be obtained in a short time.

The White Flash Generator.—This flash boiler, or generator as it is called, consists of nine coils of steel tubing placed one above the other and connected in series. In both the small and large generators used in the White steam cars the generator tubing is of one-half inch internal diameter, but the length of the tubing differs, of course, for the two sizes.

Fig. 362 shows diagrammatically the circulation of the water and steam through the generator. In operation, water is pumped into the upper coil, and in passing through each coil, it must rise to an elevation higher than the first or upper coil.

In effect, this forms a series of traps, and as is shown in the diagram, the water or steam in order to pass from one coil to that next below, must be forced up to a level above the top coil before it passes down to the next lower coil.

This trapping of the water gives the generator a certain amount of reserve capacity and prevents the water passing directly through the generator to the engine, as it would otherwise be likely to do on a hard

pull, and hot water or wet steam would be drawn into the engine cylinders.

It also prevents the steam rising to the top and the water settling to the bottom, as is the natural tendency.

There is but a very small quantity of water and steam in the generator at any given moment (in the larger car the total capacity of the generator is less than one-third of a cubic foot), but the process of making steam is so rapid with the flash system of generation, that the rate of steam production follows the changes in the intensity of the fire without any appreciable lapse of time.

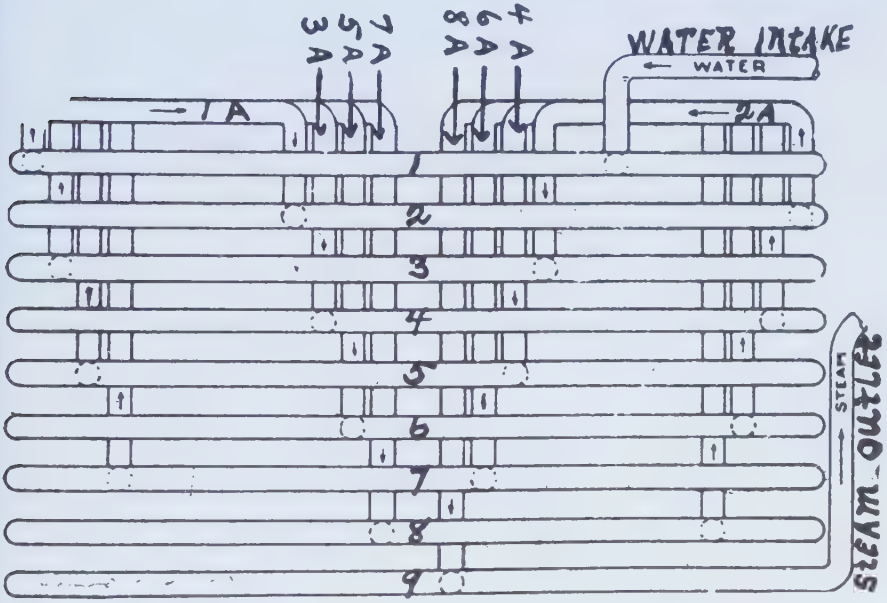


FIG. 362.—Diagram showing circulation through the White flash boiler. In operation, the water is pumped into the upper coil, through the pipe marked "water intake," passing around through coil No. 1, then up through tubing 1A, and down to coil 2, through coil 2 up to tubing 2 A and down to coil 3, through which it passes up through tubing 3 A and back down to and through coil 4, up through tubing 4 A and down through coil 5, up through 5 A down through coil 6, up through 6 A and down and through coil 7, up through 7 A, down and through coil 8, up through 8 A and down into and through coil 9, the last and lowermost coil of tubing, being directly over the fire where the steam is highly superheated, passing out of the generator from this point to the engine. The water or steam, in order to pass from one coil to that next below, must be forced up to a level above the top coil, and must then pass down again. This feature prevents water from descending by gravity, and renders the circulation down through the generator dependent upon the action of the pumps, or in other words a forced circulation.

Seamless Steel Tubing for Flash Boilers.—Improved methods in the manufacture of steel tubing have resulted in an article almost indestructible and has made possible the development and successful application of the flash system of steam generation for automobile propulsion.

Prof. Carpenter of Cornell University has subjected samples of tubing used in flash boilers, to a pressure of 18,900 pounds per square inch without showing any signs of rupture. Owing to the limitations of the testing apparatus on hand, he was unfortunately unable to ascertain the bursting strength.

Seamless steel tubing is now manufactured on an extensive scale, to meet the demands of flash boiler manufacturers and for other purposes where an article possessing great strength is required.

CHAPTER THIRTY-SEVEN.

LIQUID FUEL BURNERS AND REGULATORS.

Of Liquid Fuels in General.—All light steam carriages, and many heavier vehicles as well, use liquid fuel, oil or mineral spirit, to produce heat for their boilers. Such liquid fuel is not burned in liquid form, as is oil in an ordinary lamp, but is vaporized by heat, the vapor or gas thus produced being fed to the burner and ignited, in the same manner as ordinary coal gas used for light or heat in houses. It would be impracticable to carry gas in tanks on steam carriages, since the difficulty of storing and replenishing the supply would be greatly increased. By the use of liquid fuels a vast saving is made possible, both in space and weight, while their consumption in gaseous form is another element of economy.

Advantages in Using Volatile Fuels.—A prominent English authority on motor carriages gives the following five considerations of advantage in the use of liquid fuels:

1. Their combustion is complete, no heat being lost in the form of smoke or soot.

2. They produce no ashes or clinkers, which must be periodically cleaned out. Hence there is no loss of heat or drop in steam pressure, due either to this cause or to the renewal of coal.

3. The flues are never incrusted with soot, which involves the best conditions for use of heat.

4. The temperature of the escaping gases is lower than with a coal fire, since there is no need that the air required for combustion should force its way through a thick layer of burning fuel. Whence the uptake temperature is generally about 400°, Fahrenheit, instead of between 600° and 700°, as with the use of coal fire.

5. Since the fuel is burned in fine particles, in close contact with the oxygen of the air, only a small excess of air over that actually required for combustion is admitted to the burner. The opposite is the case with coal.

As may be readily surmised, the calorific value of liquid fuels is far greater than that of coal. It has been estimated that, taking the two weight for weight, petroleum oil has about twice the heat efficiency of coal. Since, therefore, equal weights of both varieties of fuel occupy about equal spaces, it follows naturally that petroleum products are far more economical and serviceable for use in vehicles of any description, or in boats and ships, where the considerations of weight and space occupied, in ratio to the power, are all-important.

The liquid fuels most commonly used are kerosene and gasoline, both being vaporized by the heat of the burner.

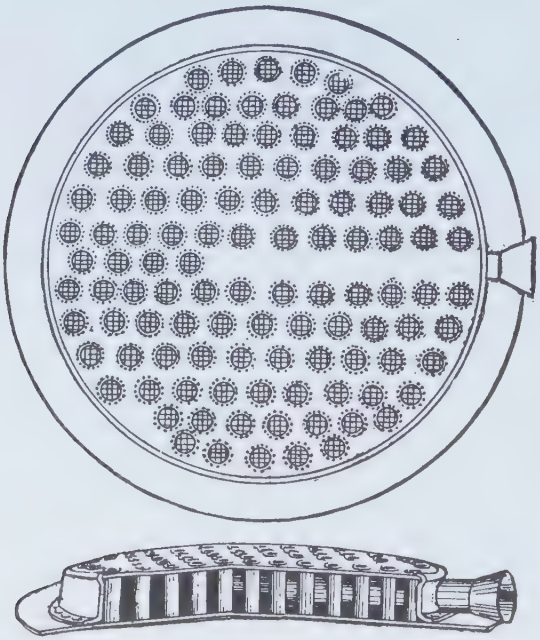


FIG. 363.—Plan and Part Section of a Typical Gasoline Burner for Steam Carriage Use.

The Gasoline Burner.—Very nearly the typical gasoline burner for steam carriages is shown in an accompanying figure. It consists of a flattened cylindrical chamber, pierced from head to head by a number of short tubes, each of which is expanded into the holes prepared for it and flanged over to make a secure joint,

somewhat after the manner of a well-made boiler flue attachment. These air tubes, as they are called, are open to the air at top and bottom, having no communication with the interior of the cylindrical chamber above referred to. The gasoline enters the chamber, from a nozzle at the end of the feed pipe and through a tube entering at one side of the cylinder and extending inward about two-thirds of the diameter. This tube is called the "mixing tube," and its function is to make a mixture of air and gasoline vapor that will burn readily in the atmosphere. Having entered the cylindrical chamber, there is no avenue of escape for the inflammable gas except through the circular series of pin-holes, which surround each one of the air tubes, as may be seen on the cut of the top of this burner. It is at these minute perforations that the gasoline gas is ignited, the combustion being rendered perfect by the air admitted through the air holes previously mentioned.

The Storing and Feeding of Gasoline.—The liquid gasoline for supplying gas to the burner of a steam carriage is carried in a tank, disposed generally to the rear of the body, and sufficiently separated from the burner to avoid all dangers that might arise from leaks or overheating. Within this storage tank a good pressure of air is maintained—generally between 50 and 100 pounds to the square inch—from a separate air tank, supplied by a pump. This pressure is sufficient to force the liquid gasoline into the vaporizing tubes, when the supply cock is opened. After it has been vaporized the circulation continues, as controlled by the steam pressure diaphragm regulator, which operates a needle valve on the tube supplying the burner, the amount of gas and liquid gasoline moving between the supply tank and the burner being thus determined. If the fire is blown out in the draughts created by travel, the difficulty may be generally remedied by using higher air pressures in the tank. Some drivers have used as high as 100 pounds and over.

The Automatic Fuel-Feed Regulator.—The fuel-feed regulator, of which there are several serviceable forms, is one of the most necessary attachments of a steam carriage. Generally, it consists of a diaphragm, which, actuated by steam pressure from the boiler, automatically closes, or partly closes, a needle valve, thus regulating the amount of fuel fed to the burner. Several such

apparatus are shown in section in Figs. 365-366. There, as may be seen, the diaphragm is fixed across the tube leading from the steam space of the boiler.

Against its inner side bears a solid head, or pressure cap, carrying a rod, at the farther end of which is a needle valve. The

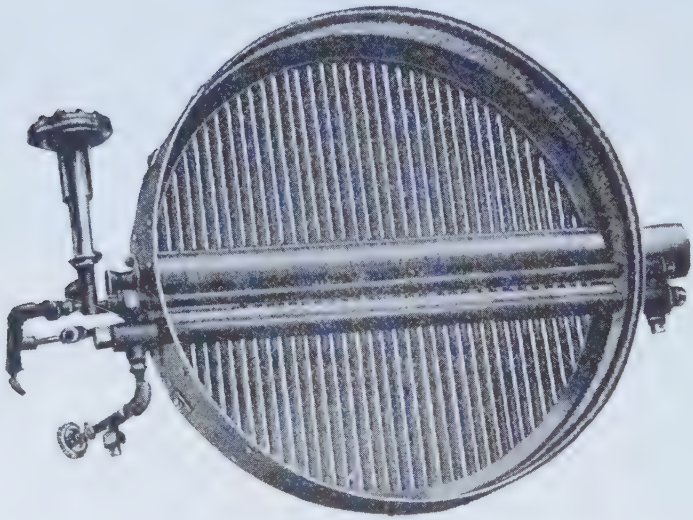


FIG. 364.—The Lane burner. This is made entirely of tubing. The mixing tube exceeds in length the diameter of the burner, thus insuring a uniform mixture of air and vapor. The flames are arranged in straight rows separated by narrow air passages, thus supplying oxygen for combustion to each side of each flame. The cut also shows the vaporizing tubes within the burner casing and the igniting torch below them. The latter is a perforated tube enclosed in an absorbent envelope. The tube is connected with a cup located outside the burner. One valve only is operated to start this burner. There is, however, a second valve in fuel feed pipe, accessible from driver's seat, and also a valve for controlling pilot light, but these are seldom used.

pressure cap is normally held against the diaphragm by a stro spring. When sufficient steam pressure bears upon the di phragm, the spring is compressed, allowing the rod attached to the head to be pushed inward, thus regulating the needle valve, according to requirement.

The instrument, thus formed, consists of two parts. The one is the pressure chamber containing the spring, whose pressure on the head is regulated by an adjusting screw, through the shaft

of which passes the valve rod. The other is the gasoline chamber, into which the fuel for the burner is admitted to the left of the point of the needle valve; its outlet being controlled, as shown, by two hand-wheel valves—one leading to the main burner through the mixing tube, the other being intended to let out a sufficient supply of gasoline to the starting device, which may be a detachable "torch," or auxiliary vaporizer, or some arrangement of drip cup and preliminary generating coil. This arrangement of the valves is shown in different cuts of burners and automatic regulators, being there sufficiently designated. Thus, as shown in the figures, the valve rod, in entering the gasoline end of the regulator, passes through a stuffing box, so as to prevent all leakage at that end.

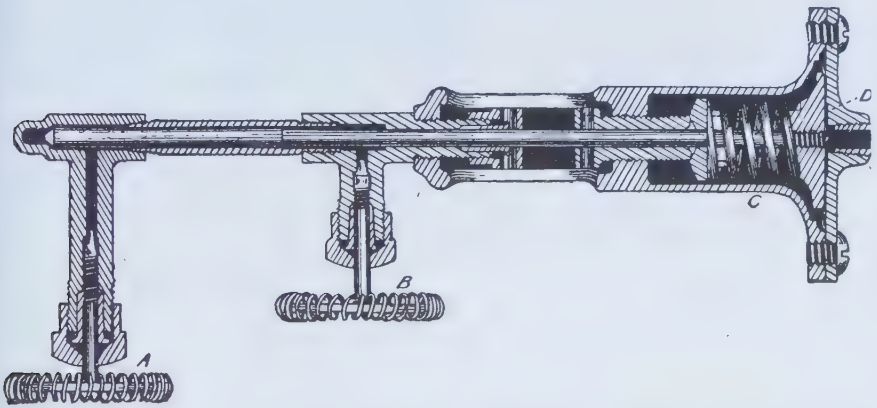


FIG. 365.—Fuel Feed Regulator of a Steam Carriage Burner, intended for Use with "Torch" Burner Kindler or Auxiliary Vaporizer. A is the hand wheel and needle valve regulating the feed to the main burner; B, the hand wheel and valve for operating the torch; C, the spring and header attached to the main valve rod; D, the diaphragm against which steam bears, regulating the main valve according to pressure. The liquid gasoline is admitted at a port on the left-hand extremity of the regulator tube, near the end of the needle valve on the main rod.

Of course, until there is sufficient heat generated to vaporize gasoline for the regular burner and generate steam pressure in the boiler, the automatic regulator cannot operate, as described, and the flow of gasoline to the starting burner or vaporizer is regulated solely by the hand valves.

Another form of regulator, shown in an accompanying cut, used on steam wagons, has the advantage of simplicity in this particular, doing away with both spring and stuffing box. The

diaphragm has concentric corrugations, and to its centre is attached a valve rod having longitudinal groovings to permit the fuel to enter the feed tube in such quantities as the pressure on the other face of the diaphragm will permit. Steam pressure, being thus brought to bear, tends to deform the diaphragm; hence compressing the valve rod and decreasing the rate and quantity of fuel feed. The fuel is supplied from the storage tank through the port into the lower chamber of the two formed by the diaphragm, as may be readily understood.

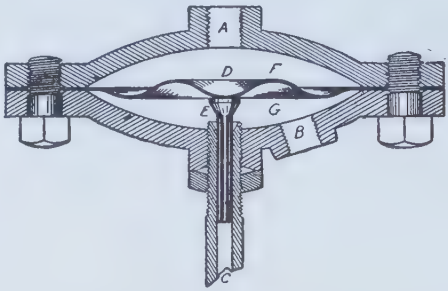


FIG. 366.—Gasoline Burner Regulator, operating with a corrugated diaphragm, like a steam gauge. A is the inlet for steam; B, the inlet for liquid gasoline; C, the port leading to the burner; D, the diaphragm; E, the head on the grooved rod of the valve; F, the steam chamber; G, the gasoline chamber.

Constructional Points on Gasoline Burners.—Several steam carriage burners are formed by riveting together a steel flattened cylindrical pressing and a plane disc, as shown in a former figure, inserting and expanding the draught tubes into suitably arranged perforations, as is done with the flues of boilers. Such a construction is apt to be faulty, however, owing to the fact that the steel plates tend to warp under the influence of heat, causing the draught tubes to leak, and the attachments to wear. The danger of these accidents has moved several inventors and manufacturers to design and produce burners formed with a cast top and steel plate base, or to cast both elements. By the use of castings warping is positively prevented, and leaking at the joints of the draught tubes is obviated.

One of the best-known burners of this construction is that widely known as the "Dayton," which possesses the additional feature of supplying gas for the burner flame through annular openings around each of the draught tubes, instead of using the

"pin-hole" design, already described. It is possible to construct with this feature, since the air tubes are cast in one piece with the head and base plates, being afterward reamed out, so as to make them uniform in size. In addition to this air opening, a counter-bore is sunk in the top plate of the burner, and a steel washer is fitted into it, leaving an annular opening for the passage of gas in the inside of the washer. The outside of the washer has a number of small openings in it, so that each air tube is surrounded by two concentric circles of flame. This construction affords a very large heating capacity, and also, as is claimed, prevents the top of the burner from cracking, also less liability

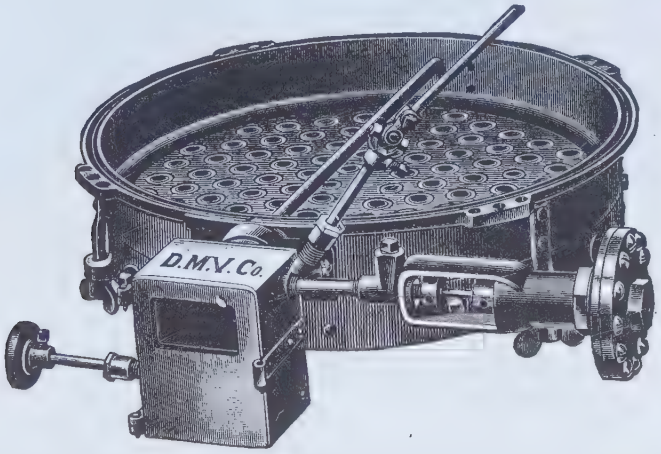


FIG. 367.—The Dayton Burner, showing the Starter Box and Regulator in Position.

of chocking with rust, dust or carbonized particles, which is a frequent source of annoyance with "pin-hole" burners.

An Auxiliary Coil Starting Device.—The starter used with the "Dayton" burner, already described, is shown on page 509, Fig. 367. There, as may be seen, a small box, called a "starter box," is attached at one side of the burner It contains a short coil of tubing, into which liquid gasoline may be admitted by opening the valve which is shown at the side. A few drops of liquid gasoline are then allowed to drip into the "starting cup," beneath the coil, and this, set on fire, will speedily generate sufficient gas to light the pilot burner, from which, in turn, the main

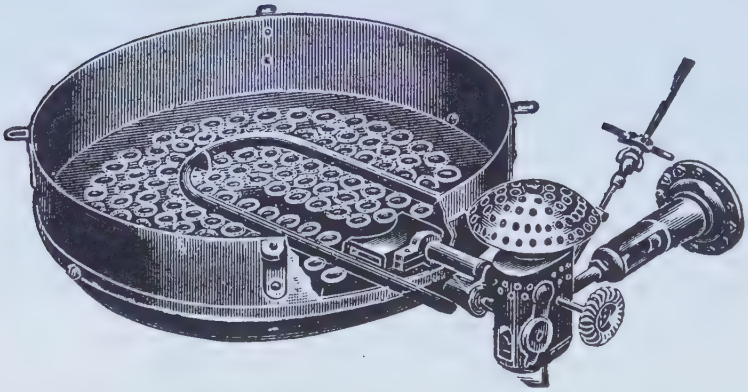


FIG. 368.—The Forg generator and burner. The gasoline supply is carried through a pipe entering on the left hand side and passing over the burner in a loop form, out on the right hand side, where it passes into the generator box. The generator box is made of sheet steel suitably perforated and so arranged that while the fire will burn freely inside of the box, it will not blaze up on the outside.

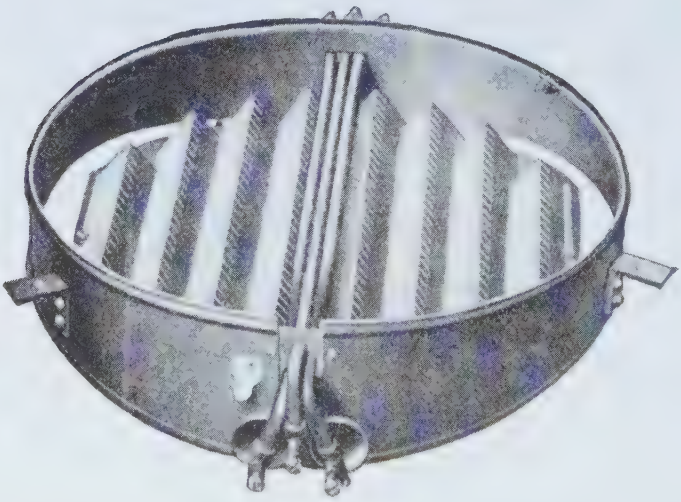


FIG. 369.—Stanley burner, showing vaporizer and mixing tubes. The burner is entirely encased, there being no air inlet except at the mixing tubes, consequently it is not affected by air currents. The pilot light is not shut off by the automatic, but burns continuously until shut off by hand and is just strong enough to hold the steam pressure.

burner may be kindled as soon as the vaporizing tubes are sufficiently heated.

As soon as this point is reached the needle valve to the main burner, shown at the right hand of the starter box, is opened, admitting gas through the nozzle into the mixing tube.

By closing this valve, the main fire may be shut off, as desired, although the pilot light continues burning, until extinguished by shutting off its supply of gas, which is never modified in any way, being out of reach of the automatic regulator controlling the fuel feed to the main burner.

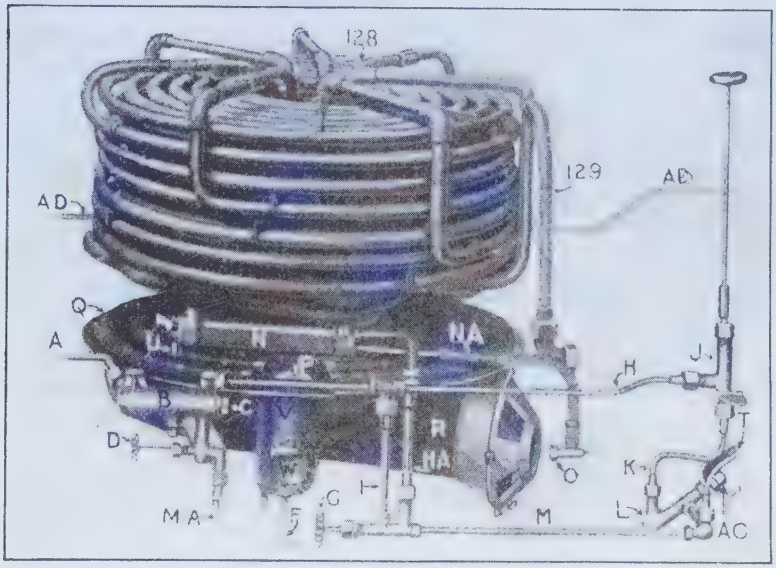


FIG. 370.—The White flash steam generator and burner. Fuel passes through pipe A, then through strainer B. From the strainer it passes through pipe H, valve J, pipe K, valve L, pipes M and HA to vaporizer N. Gas is discharged from the vaporizer through pipe NA and nozzle O into burner induction tube R. Warming up valve G is supplied through pipe I.

The White Burner and Connections.—As shown in fig. 370, the burner is of the Bunsen type, the gasoline vapor drawing back through the mixing tube R, sufficient air for good combustion.

Fuels of the lower specific gravities, such as 65 to 70 (Baume Scale) require more air than those of higher specific gravities, such as 70 to 76. The air supply may be regulated by the air shutter S on the mixing tube. Usually too much air causes the fire to burn very blue and to raise off the burner; too little air causes the fire to burn with a red and yellow

flame. The proper flame is blue, a medium between the light and heavy flame just described. If the air supply be not correctly adjusted, it causes the burner to light back to the nozzle and is sometimes accompanied by "howling."

In lighting the sub-burner, the valves D and F should be closed and main fuel valve opened which allows fuel to come through pipe A to the sub-burner V. Valve F should now be opened one turn, door W opened and a lighted match applied inside. After doing this, the supply valve D should be opened slightly, closing it again at once, leaving it open about one second. This operation is repeated until sufficient gasoline runs into the drip cup to be ignited by the match. Sufficient fuel should be kept in the drip cup by opening and closing D to warm up the sub-burner. When the sub-burner becomes hot enough to vaporize the gasoline, fuel will cease to run in the drip cup as it has now become a gas and will pass up through the pilot light grate and burn in the main fire box. Valve D should then be opened at least one turn and left open. As soon as the gasoline in the drip cup is all burnt out, this flame should burn blue and soon heat the grate red hot. This can be seen by looking through the hole in the boiler casing. As soon as the sub-burner gets warmed up, the flame should be adjusted by valve F.

This valve regulates the strength of the flame and should be turned up or down until a steady blue flame is obtained that does not roar. In case the sub-burner goes out, but is still hot enough to vaporize the fuel, it can be relighted by putting a match through the hole in the casing without using the drip cup.

When the sub-burner is to be shut off, valve D is closed and valve F opened wide. This frees the passages in the sub-burner of gas and helps to keep them clear and open. Should the flame in the sub-burner be not sufficiently strong with valve F opened two turns, there is probably some obstruction in the valve and it should be examined and cleaned.

CHAPTER THIRTY-EIGHT.

BOILER ATTACHMENTS AND AUTOMATIC REGULATING DEVICES.

Of Boiler Feeders in General.—There are two different kinds of device for feeding water to steam boilers: plunger pumps operated by the engine or by a separate cylinder; and injectors, which raise and feed the water by a steam jet from the boiler itself. Injectors are largely used for locomotives, marine and stationary boilers, but to the present time almost not at all in steam road carriages. The principal reason for this is that the valves and apertures in an injector, suited for a light carriage boiler, would have to be made so small that they would be constantly clogged with dirt and sediment, hence rendering the instrument inoperative. Furthermore, when in operation, an injector would be liable to fill the boiler too rapidly, while the pressure remained sufficient to raise the water, thus causing priming; and, if shut off until the water level had fallen considerably, would cause damage to the boiler by flooding it, while in an overheated condition.

Plunger Pumps and By-Pass Valves.—The plunger pumps used to feed steam carriage boilers are most often operated from the cross-head of the engine. Consequently, so long as the engine is in motion, water is steadily pumped into the boiler. When, as shown by the water-glass, the level is too high, the by-pass valve may be opened, and the water pumped from and back again to the tank. In some carriages the by-pass is always operated by hand; in others it is also controlled by some kind of automatic arrangement. The automatic control of the by-pass is extremely desirable, particularly since unskilled engineers most often have charge of carriages and are exceedingly liable to forget the small details of management. On the other hand, many automatic devices get out of order altogether too easily, and leave the carriage driver to exercise his skill and judgment at an unexpected moment.

In addition to the danger of flooding the boiler, the opposite embarrassment often occurs—owing to some disarrangement the pump may fail to feed enough water to the boiler, or may not operate at all. Then it is necessary to use a supplementary feeder, generally a hand pump, or a steam pump operated by a separate cylinder. Such supplementary steam pumps and injectors are commonly arranged to start automatically, as required, but may also be started by a hand-controlled valve. Another advantage involved in the use of automatically controlled steam pumps is that water may be fed, as required, to the boiler, after the engine

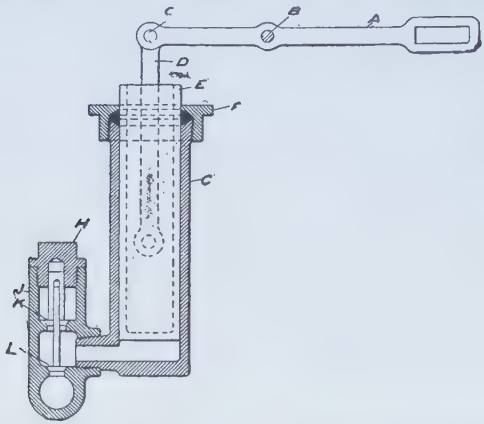


FIG. 371.—Section of a Type of Plunger Feed Pump. As is obvious, the valve opened by suction of the up-stroke is closed by compression of the down-stroke, and *vice versa*. This pump is equipped with a double, or compound, valve, which, as may be seen, secures perfect balance in operation with the simplest possible constructions. The stem of the suction valve enters a bore in the stem of the outlet valve. Referring to the lettered parts: A is the pivoted lever working the pump from the crosshead of the engine; B, the fulcrum point; C, the attachment of the piston rod, D; E, the trunk plunger; F, the packing cap; G, the pump cylinder; H, nut on the valve chamber port; J, the valve chamber; K, water outlet valve; L, water inlet valve.

has ceased motion, and it is desirable to leave the carriage standing with steam up. In this condition, however, a very small amount of water is needed, except under unusual conditions.

Operating the By-Pass Valve.—The driver of a steam carriage must constantly watch the water-glass in order to inform himself as to the water level in the boiler. On noticing that the level is too high, or is rising too rapidly—the proper level is generally about two-thirds up the glass—he opens the by-pass

valve by turning a small wheel placed near the throttle lever beside his seat. This act, as already suggested, turns the water forced by the pump back again into the feed tank, a three-way cock controlling its travel.

If, after the water has been led from the boiler for some time, the level begins to sink, it is necessary only to close the by-pass valve, thus resuming the feed. If, from any cause, the pump seems unable to keep up the water level in the boiler, and the reading of the water-glass is verified by the try-cocks, thus showing that it is working perfectly and is unclogged with sediment, a few strokes of the auxiliary hand pump will suffice, if no automatic steam pump be attached to the carriage.

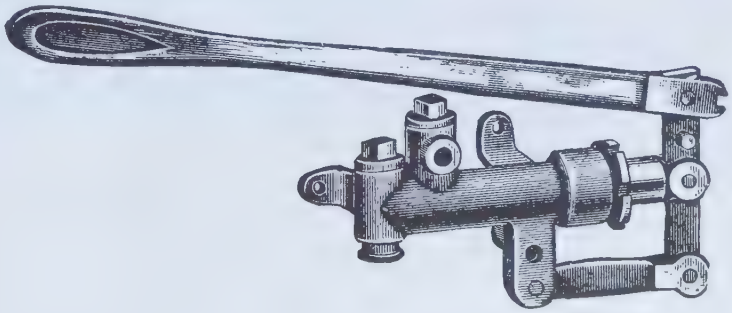


FIG. 372.—A hand feed water pump for use on cars having tubular boilers working on moderately high steam pressures. The handle is arranged to fold down when not in use.

FIG. 373.—Hand water pumps for use with flash boilers. It is intended to be placed in front of seat, between the two passengers. The bracket in center being movable, enables the pump to be placed at any height to suit the car. The water connections are for one-quarter inch pipe. The plunger is quite small as the resistance to be overcome—that due to the high working pressure of the flash boiler—is considerable, in fact it would be too great for hand operation if the plunger were large as shown in fig. 372.

Troubles With the Pump.—Since the small water pumps attached to steam carriages are of the simple plunger type, failure to supply sufficient water to the boiler may generally be attributed to loosened packings or to clogged check valves. The rapid sinking of the level in the water-glass will indicate trouble with the pump, except when ascending a high hill. In the latter case the fall of level may reasonably be attributed to the unusual steam

consumption. Under usual circumstances, the trouble is due to loosened packings, and this trouble may be remedied by inserting new packings, although particular care should be exercised, so as not to pack the plunger too tightly and cause breakage.

Boiler Attachments: Try-Cocks and Water Glass.—In operating a boiler of any design it is essential both for safety and efficiency that the engineer should be kept constantly informed on the level of the water and the pressure of the steam. For this reason boilers are fitted with try-cocks, water glass and

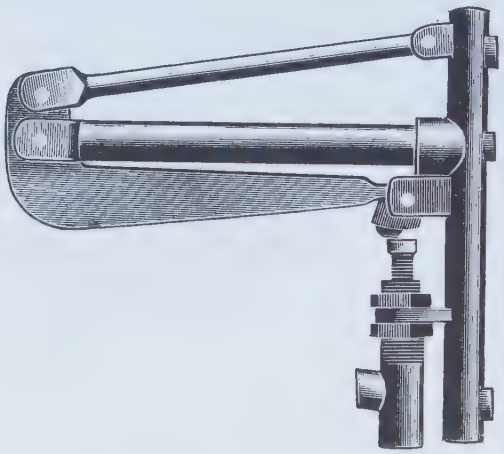


FIG. 374.—The Ofeldt automatic water regulator. This device consists of a column, having an expansion tube attached at right angles. A lever, with the fulcrum braced from the top of the water column, is attached by a joint to the end of the expansion tube, with the lever free to operate the by-pass valve. In operation, the closing and opening of the by-pass valve depend upon the expansion and contraction of the brass tube, when subjected to water at the boiling point and steam, which is over 150 degrees hotter. The water rises in the boiler, at the same time rising in the regulator water column, until it enters the expansion tube, causing the tube to contract and pulling on the lever, thus lifting the free end and opening the by-pass valve. When the water has been evaporated from the expansion tube, permitting the steam to enter, it expands and presses the lever out, thus closing and holding the by-pass valve shut. In actual operation the expansion tube finds the exact position to keep the water in the boiler always at the same level. Should the valve by-pass too much water, or not enough, it can be adjusted to shut off closer or open wider by raising or lowering the valve.

steam gauge, all of which are depicted in accompanying figures. There are usually three try-cocks, as shown, the upper one intended for steam, the second at the working level of the water, and the third at a fixed point above the fire line. In conditions of uncertainty in the action of the water glass the engineer may find out whether the water level is too low by opening the lower

cock, or may find if it is too high by opening the two upper ones. In making test it is necessary to leave the cock open sufficiently long to discover whether all steam, all water, or a mixture of both is escaping.

The water glass, or water column, furnishes a ready means for determining the exact height of the water in the boiler.

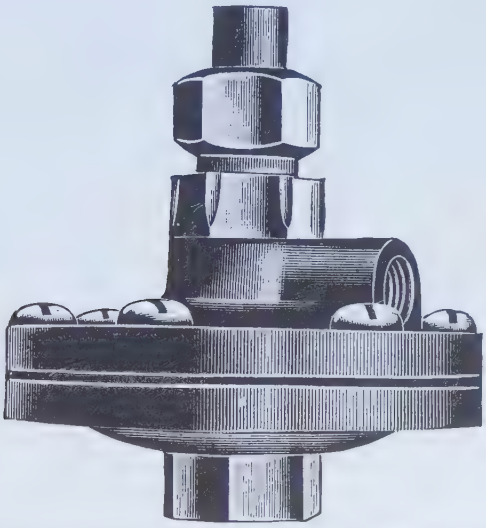


FIG. 375.—The Ofeldt automatic fuel regulator. This consists of two concave brass discs with a steel diaphragm between them, held together with screws, leaving a small space on the under side of the diaphragm for steam and a space for fuel on the upper side. The valve consists of a brass seat in the center of the diaphragm, with a specially made hollow fitting which the valve rests against. This hollow tube is the end of the supply pipe to the burner and can be adjusted to shut off the fire at any desired steam pressure by breaking the union on the upper side of the regulator. In operation, when the steam pressure on the lower part of the diaphragm has reached a point where it is desired to shut off the fire, the diaphragm is pushed upward, pressing the metal seat upward until it closes against the special hollow fitting mentioned before, thus closing the valve. When the boiler pressure decreases, the natural spring of the diaphragm opens the fuel valve and starts the fire again. The fuel enters through the opening on the side and passes down into the space on the upper side of the diaphragm and through the union fitting to the burner. Where a pilot is used, the fuel valve is constructed to shut off all the fuel supply to the main burner. These regulators are ordinarily set for 225 pounds steam pressure and 60 pounds air pressure.

Since it is such an important consideration in boiler operation that the water level should be constantly watched, it is necessary that the water column should be placed where the engineer may constantly observe it. Thus it is that, in steam carriages it is disposed in the side of the body beneath the seat, its condition being readily observable by the driver by reflection in a small

mirror set to one side of the dashboard. Lamps are also arranged behind it, so that the level of the water may be observed at night.

The water glass also gives information on the condition of the water within the boiler, as when oil or scum has collected on the surface, causing foaming.

FIG. 376.

FIG. 377.

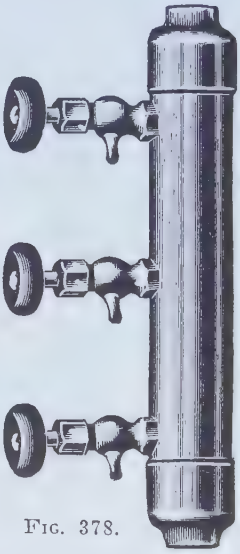


FIG. 378.

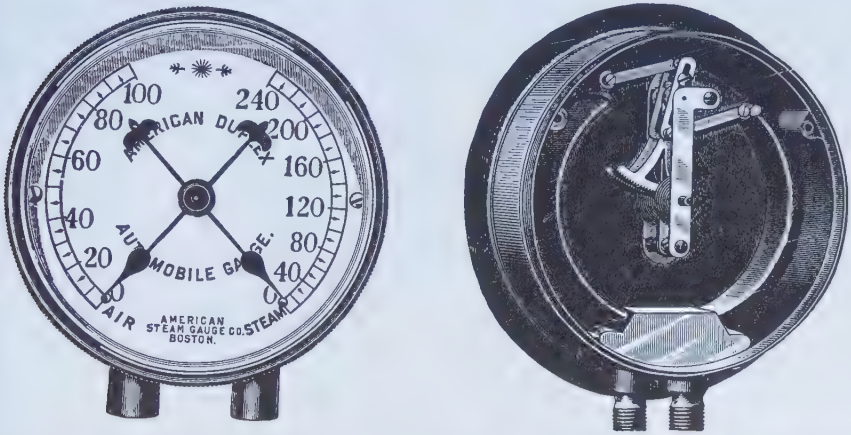
FIG. 376.—The Seabury water gauge. This device is designed to withstand any pressure possible with fire tube boilers. Observation of the water is through a series of bull's eyes of Scotch glass one inch thick, fitted into the casting with two packing rings and retained by a brass screw ring. The shape of the glass is such that the water appears a deep black as it comes over the bulls' eyes, the empty compartment above the water appearing white, showing the water level at a glance.

FIG. 377.—Klinger replex water gauge with piston glass one-half inch in thickness. Owing to the peculiar shape of the observation glass, the water appears black while the steam shines with a silvery lustre. By removing the gauge cock at the bottom and the cap at the top the inside surfaces may be cleaned.

FIG. 378.—A water column with try cocks for ascertaining the water level in the boiler. In operation, the cocks should be only partially opened otherwise the water will be raised in the column which will show a false level.

Troubles with the Water Glass.—Troubles with the water glass that must be constantly guarded against are stoppage by sediment and the breaking of the glass tube. The former difficulty may generally be remedied by closing the lower cock and allowing the steam from the upper one to blow through the

drain cock shown at the bottom. In case the glass tube be broken it is necessary only to close both cocks, and insert a new tube in the collars, having first removed the nuts and packings at top and bottom. In order to obviate, as far as possible, breakage of the glass it is necessary to avoid too sudden changes of temperature in the column, when first opening the cocks, after getting up steam.



FIGS. 379, 380.—Dial and Interior View of the "American" Duplex Combined Steam and Air Pressure Gauge for Use on Steam Carriages. The dial has two hands; one of them attached to a sleeve which works over the spindle carrying the other, in the same manner as the two hands of a clock are hung. As may be readily understood, the two hands work in opposite directions, one clockwise, the other counter-clockwise, from zero to maximum on their respective scales. The sectional view shows the mechanism by which this result is accomplished: two separate inlets, for steam and air, respectively; two distinct flattened and curved steel tubes, each attached at its end by a link to a lever and toothed sector working on the toothed pinion concentric with the pivot of one of the hands. The two flattened tubes, of course, have different tensile ratios, causing them to tend to straighten at different pressures. Hence the steam hand records a maximum pressure of 240 pounds, while the air hand records a maximum pressure of 100 pounds.

Most of the water glasses used on steam carriage boilers have self-closing valves, which operate to prevent the escape of steam in case the glass is broken. In the use of these valves particular care is needed, since they are very liable to be clogged with sediment or incrustation, causing false indications of the water level and enabling the boiler to be burned out before the driver knows that anything is wrong. Several carriage owners, in the writer's experience, have had these valves removed, and contented themselves with closing the cocks every time the glass is broken. This may be a rather exceptional experience, but it is extremely de-

sirable, if not imperative, to verify the water glass reading by the try-cocks before starting the carriage.

The water glass is an important piece of mechanism, and cannot be too closely observed and cared for. Skilled engine drivers take its record constantly, and so very important is it that no error regarding the water level should be made that some inventors have proposed using colored floats to attract the driver's eye, and enables readier reading of the record. A supply of glass tubes should always be kept on hand in a steam carriage so that breakage may be immediately repaired. Also, every possible pre-

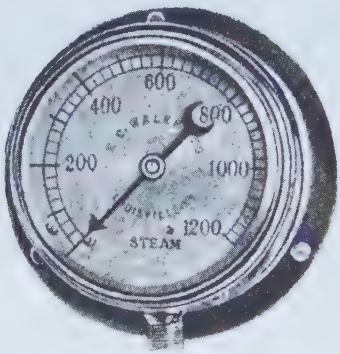
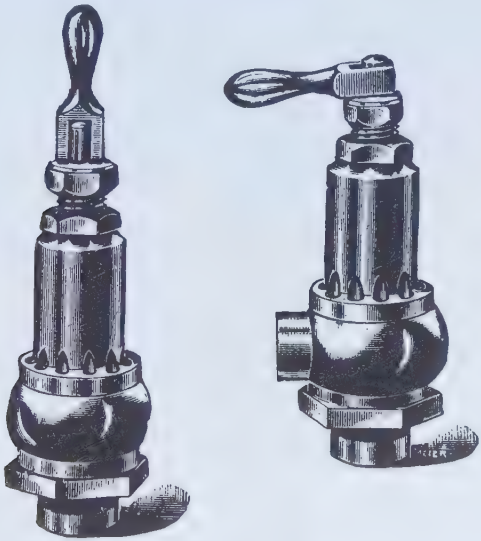


FIG. 381.—A steam pressure gauge for use with flash boilers. It is constructed for indicating pressures up to 1,200 pounds to meet the operative conditions of the flash boilers which carry much higher steam pressure than the ordinary tubular boiler.

caution should be adopted to prevent the accumulation of sediment that might obstruct the free passage of the water into the glass. It is well to clear the tube by flushing with steam at frequent periods.

The Steam Gauge.—As a means of determining the power output, a steam gauge is attached to all well-appointed boilers. This device indicates on a dial the degree of pressure generated within the boiler. Steam gauges are constructed with one of the two varieties of internal mechanism In the first variety the steam bears upon a diaphragm, regulated to yield in proportion to the pressure exerted. The second variety operates through the tendency of a flattened and bent metal tube to straighten out under pressure of the steam or gas within it. As shown in an accompanying figure, a tube, flattened to an ellipsoidal cross section, is

connected by one end to a steam pipe leading direct from the boiler. When the cock is opened, steam is admitted to the tube, its pressure tending to change the flat section to one more nearly round, and in the process causing the tube to begin uncoiling itself in the direction of a straight line conformation. Hence the other end of the tube, attached, as shown, to a link connected to a lever bearing a toothed segment, tends to move, causing the link to move the lever.



FIGS. 382 and 383.—Two views of a type of safety valve suitable for use on fire tube boilers which furnish steam at moderate temperatures. A snap lever is provided as shown for holding valve open. When getting up steam the lever is turned to the vertical position fig. 382. This opens the valve which should remain in this position until all the air is expelled from the boiler and steam begins to issue through the opening when the valve should be closed by turning the lever to the horizontal position as shown in fig. 383.

Safety Valves; Construction, Theory and Operation.—Explosion in a steel-shell, copper-flued carriage boiler is very nearly impossible, and with moderate care and watchfulness the burning out or collapse of the tubes can be prevented.

The unskilled engine-driver is amply protected, if he only exercise reasonable prudence by the automatic burner regulator, the automatic low water alarm, the water glass and steam gauge in plain sight, and lastly by a safety valve adjusted to blow off at the proper pressure.

A safety valve is simply a valve of ordinary description, arranged to close a steam pipe outlet, under pressure of a weight or spring.

The safety valves used on steam carriages are constructed on the same general principles as any of the spring valves used on locomotives, or other boilers. They are usually known as "pop" valves, from the fact that the steam in lifting the valve from its seat usually makes a "pop" or sudden detonation. As a usual thing carriage valves are adjusted to a fixed pressure, which is never disturbed.

FIG. 384.—A pop safety valve designed especially for use with superheated steam. The spring, as is shown in the figure, is not enclosed and is therefore protected from the high temperature of the steam. This is necessary as intense heat soon takes the temper out of the spring and destroys its elastic properties.

The Blow-Off Cock.—This is an important attachment of all boilers, furnishing a ready means of removing the water from the boiler under pressure of its own steam, which is called "blowing-off." It is also used in some carriages for attaching a hose to fill the boiler at starting, or for injecting water for cleaning the interior. It is usually closed with a box nut for receiving a wrench, but sometimes by a cock, as in large boilers.

CHAPTER THIRTY-NINE.

STEAM SYSTEMS.

Types of Power Plants.—In the generation and application of steam as a motive power for automobiles, numerous combinations of engines and boilers of different types have been tried, together with varied methods for securing automatic control of the fuel and feed water.

These numerous steam systems, may be classified in several ways, as follows:

1. With respect to the method of generating the steam as:

   a. By shell, water tube or semi-flash boilers, carrying a water level, and furnishing steam at medium pressures.
   b. By flash generators, which do not carry a water level, furnishing steam at high pressures and with considerable degree of superheat.

NOTE.—The terms, medium pressures and high pressures are used only in a relative sense. All steam pressures carried on automobiles are high when compared to those in use for other requirements. For instance, side wheel steamboats run with 25 to 50 lbs. steam, Corliss engines, 50 to 150 lbs., locomotives, 150 to 225 lbs., triple expansion marine engines, 175 to 300 lbs. For automobile work, 300 to 500 lbs. may be called medium pressures and 500 to 1000 lbs., high pressures. A steam gauge, registering up to 1200 lbs. is shown in Fig. 381.

2. With respect to the manner of working the steam in the engine as:

   a. Simple (sometimes called high pressure);
   b. Compound or two stage expansion.

3. With respect to the disposition of the exhaust steam from the engine, as:

   a. Non-condensing;
   b. Condensing.

4. With respect to the structural features of the engine, as:

   a. Single acting;
   b. Double acting;
   c. Duplex (two simple cylinders);
   d. Multi-cylinder.

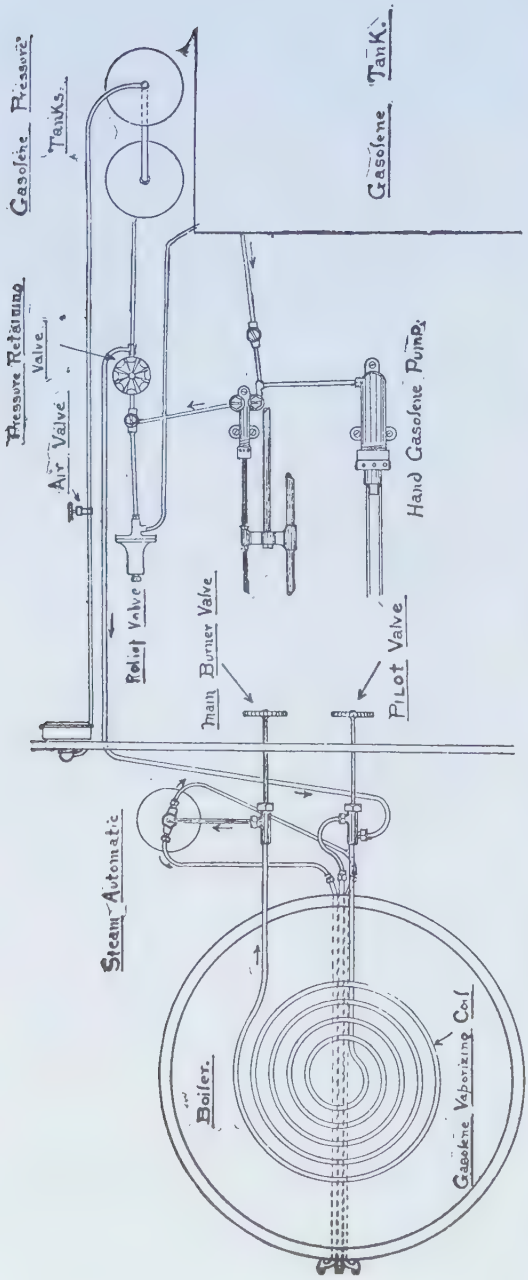


FIG. 385.—Fuel connections of the Stanley system. A pump operated by the engine, pumps gasoline from the main tank where it is carried under no pressure to the pressure tanks. The pump delivers an excess quantity of gasoline which accumulates in the pressure tanks until the pressure is raised therein sufficiently to operate the relief valve which by-passes the supply to the main tank until the pressure again falls.

Of the numerous combinations possible with the different types of engines and boilers, there are three which are in general use:

1. A shell boiler with duplex engine operating at medium pressures.

2. A semi-flash boiler with compound condensing engine operating at medium pressures.

3. A flash boiler with compound condensing engine operating at high pressures.

These three systems will be explained by describing the operation of three well known steamers, viz.:

1. The Stanley;
2. The Lane;
3. The White.

Before explaining the operation of the White Steamer, a short description will be given of a system devised in 1889, by Serpollet—the pioneer in the field of flash steam generation.

The Stanley System.—The Stanley steamer is propelled by a two cylinder, double acting, high pressure steam engine of the locomotive type, with plain D-slide valves operated by the familiar link motion valve gear. Steam is supplied by a fire tube boiler. Both the engine and boiler are illustrated and described in Chapters thirty-five and thirty-six.

Automatic devices are incorporated in the system which control the fuel and feed water supply.

Fuel Connections.—Gasoline is carried in a tank under no pressure. From this tank it is pumped as used to a receiving reservoir, consisting of two small pressure tanks situated side by

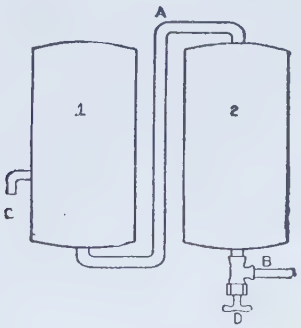


FIG. 386.—The Stanley gasoline pressure tanks. A, is the pipe connecting the two tanks; B, the pipe through which gasoline is pumped; C, the air valve through which air is pumped with the hand air pump; D, a valve for drawing gasoline out of the tank when desired.

side, so piped that the bottom of one is connected with the top of the other, as shown in fig. 386. The main tank, pressure tanks and various pipes and connections comprising the fuel system is shown in the diagram fig. 385. The operation is as follows: Assuming the pressure tanks to be empty, gasoline is pumped by the hand pump until the pressure gauge registers between ten and fifteen pounds.

The effect of this is to nearly fill pressure tank number two with gasoline, the air in this tank being forced by the gasoline into tank number one and is compressed with the resulting pressure as indicated by the gauge.

The pressure in tank one is further increased by attaching the hand air pump to the air valve and pumping till the gauge indicates eighty or ninety pounds which is the working pressure.

If the fire were now lighted, and allowed to burn for some time, the gasoline pressure would gradually drop. In this case it is to be raised again by additional use of the hand pump.

With steam up and the car running, the gasoline is supplied by the power gasoline pump operated by the engine. This pump being proportioned to deliver an excess supply of fuel, an automatic relief valve is provided, adjustable as to pressure, through which the excess passes back into the main tank.

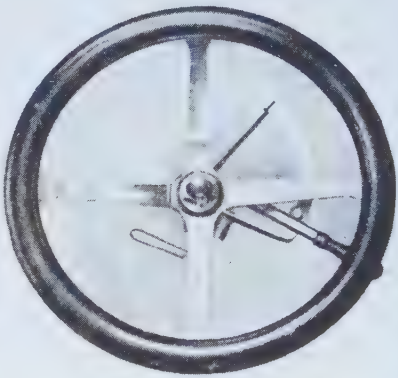


FIG. 387.—Stanley steering wheel, with hands showing how the throttle lever is lightly gripped in the fingers without moving the hand from the wheel.
FIG. 388.—View of Stanley steering wheel, showing the single throttle, locked by its locking screw, and the by pass lever which controls the supply of water to the boiler.

The air in the pressure tank will be gradually absorbed, and more will occasionally have to be supplied by the hand pump. The need of this will be indicated in two ways: 1, when running, the hand on the pressure gauge will be seen to vibrate, and 2, when standing with the pilot burning, the pressure will drop rapidly, owing to too little air for expansion.

To be certain the drop in pressure is due to want of sufficient air, and not to a leaky automatic, the latter is cut out by closing the pressure retaining valve. If now, the pressure continue to fall rapidly, the cause is insufficient air in the pressure tank.

Water Connections.—The system of pumps and piping for the feed water supply is shown in fig. 390. There are two power pumps, one hand pump, by-pass valves and a water indicator.

The two power pumps work continuously when the car is running and have a capacity sufficient to supply the boiler when running up hill or over bad roads. Hence, they must of necessity pump too much water when the car is operated on good roads. To prevent the boiler filling with water under these conditions, a by-pass valve operated by hand is provided which when open, allows the water from the pumps to be returned to the tank instead of into the boiler. By hand control of this valve the desired water level is maintained in the boiler. The pumps are so

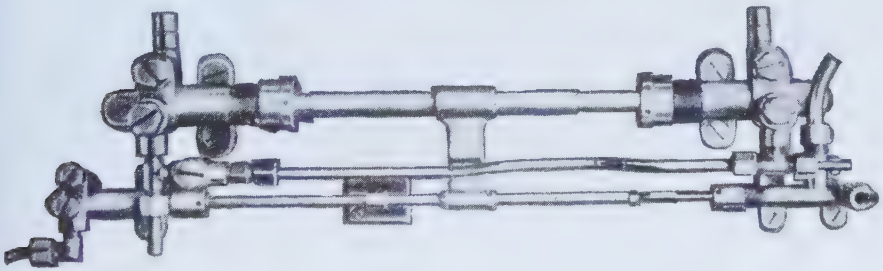


FIG. 389.—Water, gasoline and cylinder oil pumps of the Stanley car. As shown in the illustration, the four plungers form one moving part. The two large pumps are for water, one or both of which may be by-passed by the lever on the steering wheel.

connected that one or both may be by-passed, the by-pass valves being operated by a lever on the steering wheel.

If the pumps become *air bound,* that is, if the pump cylinders and valves become filled with air it will fail to deliver water.

The reason for this is that the air will be simply compressed and re-expanded as the plunger goes in and out, hence, no water would enter the pump.

To remedy this, it is only necessary to open the by-pass for a moment. The pump being thus relieved of boiler pressure, the air will be pumped out through the by-pass and the pump will fill with water and become again operative.

Instead of the ordinary form of glass water gauge, a special water indicator is used as shown in the diagram fig. 391.

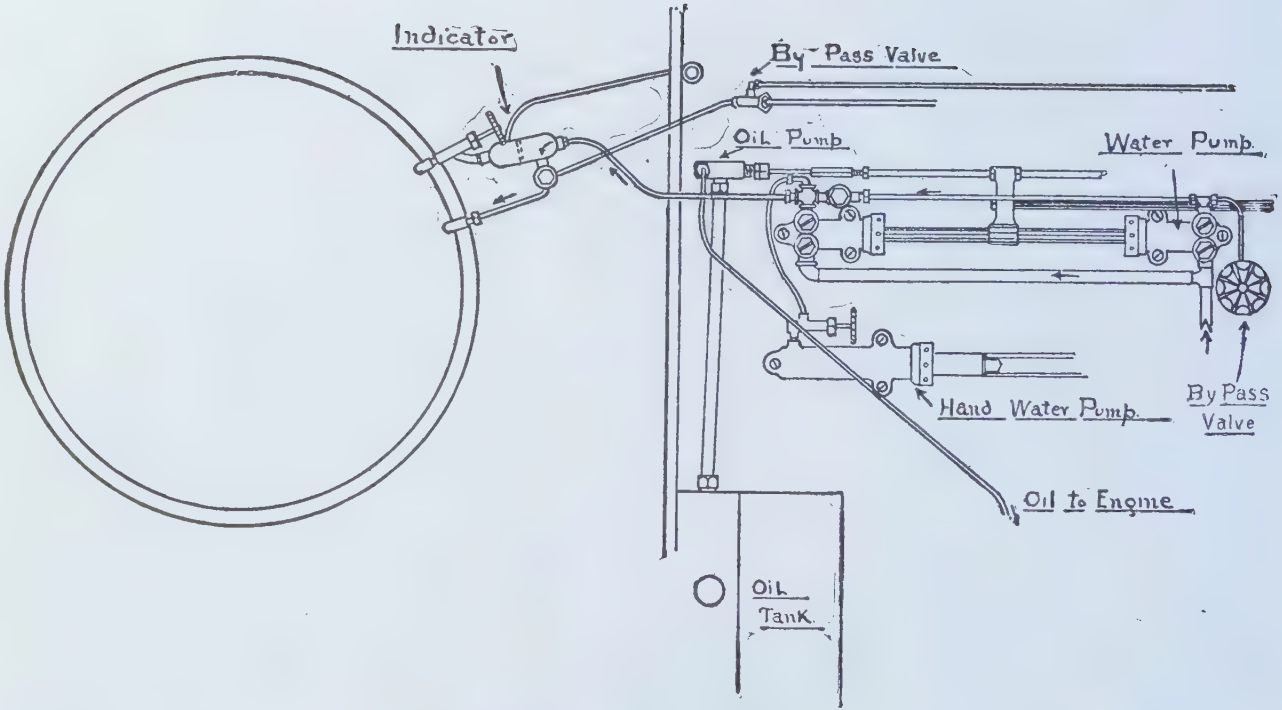


FIG. 390.—Water and lubricating connections of the Stanley system. There are two water pumps, one of them for ordinary use controlled by the by-pass on the wheel, and the other for emergency duty with its by-pass on the footboard. Both water pumps and the oil pumps are driven by the engine. The water pumps have a capacity sufficient to supply the boiler when running up hill and over bad roads. The capacity is therefore too great for ordinary conditions, hence the use of the by-pass operated by hand which allows the water to be returned to the tank when too much is being pumped into the boiler. The oil pump supplies oil to the engine cylinders. Oil enters the pump barrel by gravity and is sent by the plunger through a check valve to the main steam pipe The length of the plunger is adjustable and determines the rate of oil delivery.

The construction of this device is as follows: A water column F is so connected with the boiler at its top and bottom, that the water will stand at the same level in the column as in the boiler.

Connected with the water column at D, about eight or nine inches above the bottom of the boiler, is a casting which may be called the *indicator body,* containing two adjacent chambers G and H, one of which fills from the boiler through the connection D.

Through the other chamber the feed water is pumped, whether going to the boiler or through the by-pass back to the tank. This

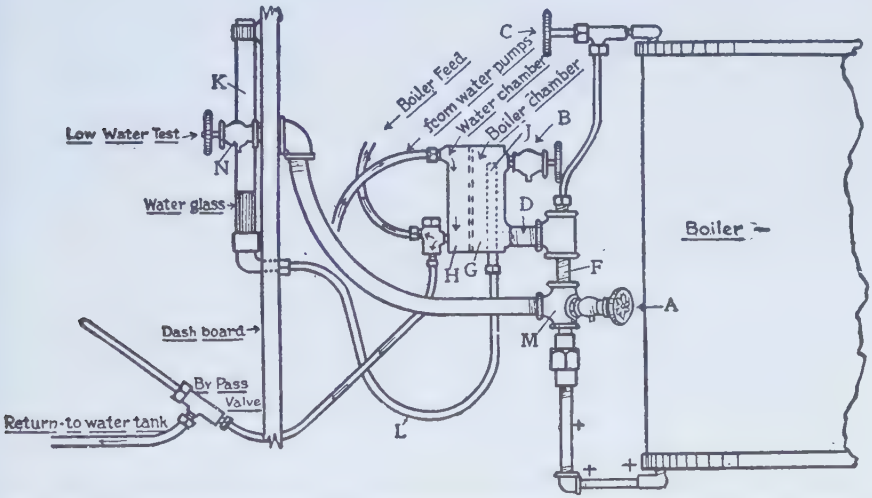


FIG. 391.—Stanley system of indicating water level. A, is a blow off and try cock; B, try cock; C, shut off valve. In cleaning out, cock C is closed and cock A opened when steam is up.

latter chamber may be called the *water chamber,* and the other the *boiler chamber.*

It is evident, that the "boiler chamber" will be filled with water provided the water in the column is above the connection D; otherwise it will be filled with steam.

The indicator proper is a "U" tube, one end of which J is of metal and sealed at the top, and called the "standpipe." This end is inserted some distance up into the "boiler chamber," and is at all times surrounded by either steam or water.

The other end of the "U" tube is a glass tube K, placed vertically on the dashboard. This "U" tube is filled with water so that the standpipe J is filled entirely, and the water when cold stands in the glass an inch or two from the bottom.

The operation of the device is as follows: As long as the chamber G surrounding the standpipe is filled with water and the feed water is being pumped through the other chamber H, it will keep the water in the former chamber comparatively cool, and also the water in the standpipe, and the water will remain at a low point in the glass.

As soon, however, as the water gets below the connection D, the "boiler chamber" will fill with steam, and, as it surrounds the "standpipe" it will vaporize some of the water in it and force the water out of it and up in the glass, thus showing that the water level in the boiler is below the indicator. Whereupon the pump by-pass should again be closed until the water falls in the glass again, which will indicate that the water in the boiler is above the connection D on the indicator.

Usually when the car is standing the indicator will receive sufficient heat to throw the water up into the glass. In this case, if the water in the boiler is above the connection D, it will immediately cool off, and the water will drop again in the glass when the car is run and water is pumped through the "water chamber."

The copper tube L leading from the standpipe extends downward six or seven inches before bending upward again to the water glass bracket, so that the hot water or steam from the standpipe will not pass up into the water glass.

Some three inches below the connection D, mentioned above there is another connection M and a pipe from this leading up through the dashboard, at the end of which is a petcock N, indicated on the sktech. This is called the low water test.

As long as the water covers this connection this petcock will remain comparatively cool, and if opened, water will come out. If, however, the water should get below this connection, the pipe will fill with steam and the end will become burning hot, and if the petcock were opened steam would come out. By this

means the operator can determine whether or not the water in the boiler is getting near the point where the fusible plug would melt out.

When the boiler is cold, whether or not it contains water, the water will always be low in the glass. Consequently, before lighting the burner, one of the petcocks should be opened and the siphon valve opened, so as to vent the boiler. If water come out of the petcock, it indicates that the water in the boiler is above that point. If not, it is below that point. The petcock should be kept open long enough to allow any water that might be in the tube to run out, provided it happened to be held there by capillary attraction when the water in the boiler was really below the petcock.

The operator should never start the fire until he is certain that there is water in the boiler.

The connection betwen the bottom of the boiler and the bottom of the water column must be kept clear, otherwise the water might remain in this column, even if there were none in the boiler.

This is cleaned by closing valve C and opening the petcock A, when there is steam in the boiler. This will blow out any sediment that may be in the lower end of the water column.

If the water indicator is to be used in freezing weather, a mixture of glycerine or alcohol and water, one to one, is employed in the "U" tube to prevent freezing.

It is sometimes desirable to test the indicator to see if it be working properly. To do this, the boiler should be well filled with water, say considerably above connection D.

With steam up and petcock B opened, hot water or steam will flow through the boiler chamber of the indicator, and if the indicator be working properly, the water should rise in the glass.

Now, if petcock B be closed and cold water be pumped through the water chamber of the indicator by the hand pump, the boiler chamber will be cooled which will cause the water to again fall in the glass.

The pumping may be done with the by-pass open which saves pumping against the boiler pressure.

The familiar torch method is followed in starting the burner, a small gasoline torch being provided for the purpose. To start the fire successfully, both main burner nozzles and the pilot nozzle should be heated and then the pilot lighted. To do this, the valve is opened one turn and the torch flame immediately

pointed into the peek hole, its slide having been previously opened. After the pilot is lighted, this slide should be closed before turning on the main fire. The latter operation should be performed by opening the main valve slowly so that the fire will come on gradually.

The Fusible Plug.—If the water in a fire tube boiler were all evaporated, and the fire kept burning, the boiler would become so heated as to cause it to leak badly.

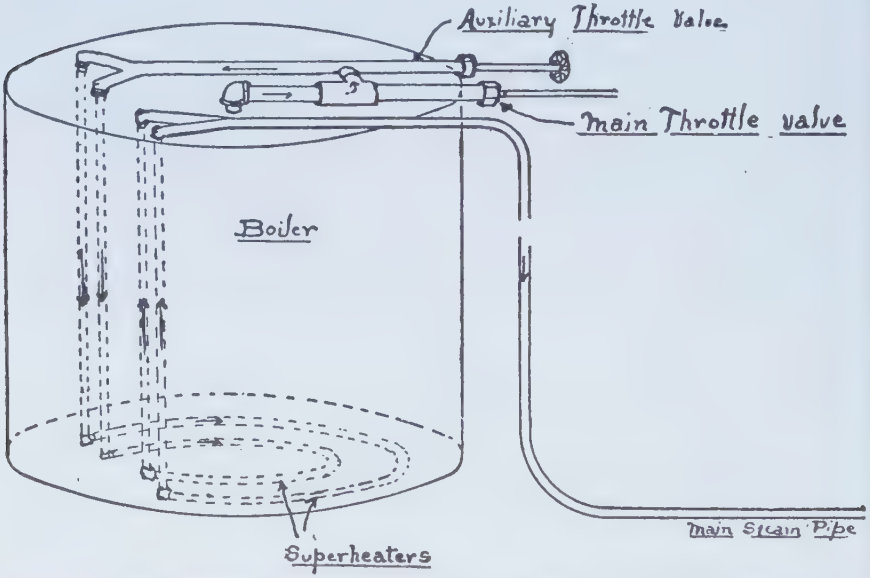


FIG. 392.—Steam connections and superheaters of the Stanley system. The elbows on the superheater, main steam pipe and fusible fitting are made on a taper and driven through the boiler tubes. They are removed by prying under the elbow and hammering at the same time.

To avoid this, the boiler is equipped with a fusible plug. When the water in the boiler gets within three inches of the lower tube sheet, the plug melts, and the noisy escape of steam notifies the operator, who immediately shuts off the fire, both pilot and main burner, thus protecting the boiler from injury. When the plug blows and the fire is shut off, it is a good plan to continue running till the steam pressure is so reduced as to compel a halt. The by-pass is then closed and water pumped into the boiler till it is cool enough to allow the plug to be removed, a new lead inserted and the plug replaced.

The pumping may then be continued till the boiler is one-third full when the fire may be lighted. Usually this can be done without reheating the torch, provided the renewing of the plug has been quickly done. The material in the plug is common lead which melts at 618° Fahr.

The Lane System.—The power plant of the Lane steamer consists of the following elements:

1. Cross compound engine;
2. Condenser;
3. Feed water heater;
4. Semi-flash boiler;
5. Control: automatic regulating devices for fuel and water;
6. Auxiliary Control: hand regulating devices;
7. Fuel and water tanks and connections.

The boiler is designed for a working pressure of 500 pounds, the running pressure being 300 pounds.

It consists, as previously described, of a series of semi-flash coils, a separator, and a fire tube shell, the combination delivering to the engine a supply of steam slightly superheated by the fire tubes which is favorable to economical operation.

Fuel Connections.—The burner is started by the operation of one valve. There is within the burner casing an igniting torch below the vaporizing tubes. This torch consists of a perforated tube enclosed in an absorbent, non-combustible envelope. The tube is connected with a cup conveniently located outside the burner.

In addition to the valve for operating the burner, there is a second valve in the fuel feed pipe, accessible from the driver's seat, and also a valve for controlling the pilot light; these valves are used only occasionally.

The burner is open 1/8 inch between the 3/8 inch diameter burner tubes, so as to ensure a sufficient supply of oxygen for complete combustion, and the 2½ ins. dia. mixing tube is carried 3 ins. outside of the burner casing so as to cool the mixture enough to prevent firing back into the burner and mixing tubes.

The blow out of the burner flame is prevented by reducing the inner mixing tube to 1¼ ins. inside diameter and by fitting a cowl closed on the top, bottom, front and outside, air taken in at the rear of the cowl, which acts both as a wind shield and mud guard.

The Gasoline Tank.—The fuel supply is contained in a cylindrical tank having oval ends. A tank of seventeen gallons capacity is provided for the twenty horse power engine and one holding twenty-two gallons for the thirty horse power engine. A

pressure of 60 pounds is maintained in the tank, this pressure being maintained automatically. The air pump is located on the left side of the engine.

The maximum air pressure available is determined by the pump clearance. This clearance space (between the pump valves) can be adjusted through a considerable range by a screw reached from the outside.

An independent steam pump is provided for emergency use.

The Water Connections.—The feed water to the boiler is regularly pumped by a crosshead pump on the engine, which has a capacity in excess of requirements, the level in boiler being regulated by an automatic by pass connected to the delivery pipe from engine pump which, when open, allows the water pumped to return to the tank again, but if closed all the water pumped must go into the boiler.

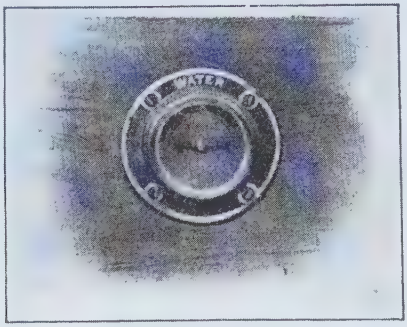


FIG. 393.—The Lane water indicator as it appears on the dash. It forms a part of the by pass apparatus and its essential feature is an expansion tube. It is connected by pipe to the boiler at the desired water level.

There is also for emergency use an independent steam pump, the reserve power of boiler permitting its use either standing or running, and a hand pump under the foot board.

The Water Tank.—This is located between the condenser and the boiler, and is piped to the engine feed water pump, the water steam pump, and the water hand pump.

Connection with the condenser is near the top of the tank and a water overflow pipe three-quarter inch below the condenser pipe, top end affords a steam exit.

The Water Indicator.—This device for ascertaining the water level in the boiler consists of a dial indicator located on the dash as shown in fig. 393, operated by an automatic by pass illustrated in fig. 394. Its essential feature is an expansion tube which is located above the hood and in front of the dash and connected by pipe to the boiler at the desired water level.

If water in boiler be below that point the expansion tube will be filled with steam and being hot is consequently in an expanded condition, and by suitable mechanical means it then holds the by pass valve shut and the indicator hand in its corresponding position.

When the water level in the boiler rises above the point of connection, the pipe becomes filled with water and the tube cools. It consequently contracts, opens the by pass valve, and moves the indicator hand.

A second expansion tube acts from a lower point on the boiler and moves the indicator hand still further around if the water level recedes below the normal.

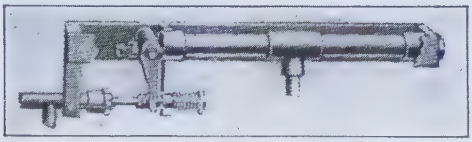


FIG. 394.—The Lane automatic by pass. This is operated thermostatically, that is, by the expansion and contraction of a metal rod brought about by temperature changes which depend on the height of the water in the boiler.

The Condenser.—The exhaust from the engine, instead of being discharged into the atmosphere, as is done in the Stanley system, is led by suitable piping to a condenser in which it is cooled, condensed and returned to the water tank.

The compound type of engine is especially adapted to run condensing, as the steam is exhausted at a lower pressure, than is done with a simple engine. The exhaust steam is not so hot and hence, the proportions of the condenser capable of condensing the steam is less than would be required with a simple engine.

The Lane condenser as shown in fig. 395, consists of five vertical rows of flattened brass tubes opening into a top header to which the exhaust is piped, and to an unobstructed base cavity which is piped to the top of the water tank.

The discharge of this condenser to the water tank is intermittent, a quart or so at each discharge, from the base cavity of the condenser.

This condenser piping avoids a water pump between the condenser and the water tank, though the bottom of the condenser is about 30 ins. below the tank top.

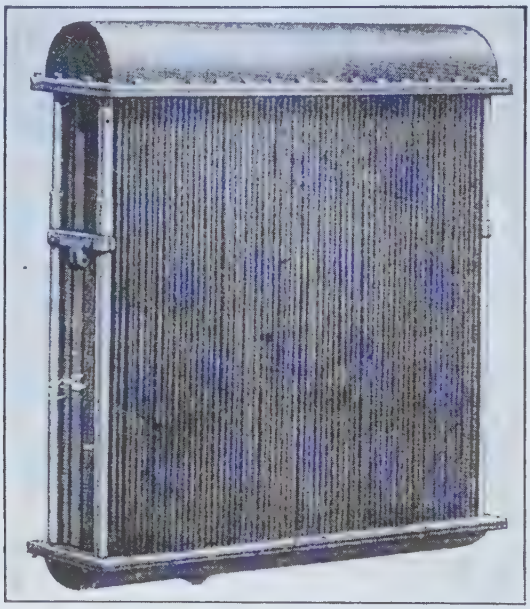


FIG. 395.—The Lane condenser for condensing the exhaust steam from the engine. It is constructed of thin, flat, brass tubes arranged vertically, with their edges toward the front, and air spaces between them. They are all secured to a common header with detachable covers at top and bottom; steam being introduced in the top one and the water piped from the lower one directly back to the dome of the tank. There is a still larger vent from the dome of tank to the atmosphere below the car. There is no pump or outboard relief, the water being returned from condenser to tank by back pressure, which rarely exceeds one pound and is usually much less. Inside the top header is a coil for heating the feed water on its way to the boiler.

Control System.—Before beginning to raise steam the driver tries the gauge cocks screwed directly into the boiler shell; if no water shows at the gauge the hand force pump is worked to fill the boiler to the gauge from the water tank. There are 3 gauge cocks; water at the lower cock indicates enough to raise steam.

To raise steam: 1, the air down draft damper on top of the hood is opened to permit a free passage of air to the burner; 2, a

door in the side of the hood at the bottom of the boiler is opened, giving access to the "heater cup" into which about a fluid ounce of alcohol is poured, this going to a horizontal pipe, perforated and asbestos clothed, placed below the gasoline vaporizing tube; 3, the asbestos pipe clothing alcohol wick is lighted, and 4, a hand needle valve between the vaporizer and the burner middle mixing tube is opened, to permit the gasoline vapor injection to the burner main middle tube.

As soon as the gasoline vapor begins to escape from the small holes in the tops of the burner tubes it is fired by the flame of the heating tube and everything is left as it is until the steam gauge shows 300 lbs., and the car is ready to run.

The operation of getting up steam usually takes about ten minutes.

As soon as steam is raised, the top air damper is closed and steam is turned on to the forced draught ejector, which sucks air up through the burner and boiler flues and then forces the product of combustion down to the open lower end of the vertical down draft tube, which is about 5 ins. diameter and extends downward to about the bottom of the burner.

The engine can be started by moving the ratchet retained hand lever on top of the steering wheel, as soon as there is steam pressure enough in the boiler, and after the engine begins working the water level and fuel supply are automatically controlled.

There are two vertical levers: the latched, outside one, is pushed forward to apply the external rear hub drum brake bands through a full length evener. The latched, inside hand lever, works the tumbling shaft to make the link valve motion give an earlier or later cut off, and the reverse.

The forced draft steam valve is opened and closed by a small T-handle on top of the steering wheel.

There is one pedal on the foot board, which is pushed forward to apply the balance gear drum brake band, ordinary brake.

A plunger pedal at the left of the steering column is depressed to change the engine from compound to simple, the engine returning to compound as soon as this plunger pedal is released.

The stop valve between the boiler and throttle is opened and closed by a wooden hand wheel at the front left of the foot board.

A small handle in the middle of the front board rear face controls the boiler water supply independently.

A long vertical glass tube at the right of the front board shows the water level in the tank.

The large, hand worked plunger glass oil cup at the top left of the front board, supplies lubricating oil to the two independent steam pumps.

The Auxiliary Control System.—This is operated by eight valve handles as shown exposed in fig. 396 by the removal of the cover.

It should be understood that this auxiliary control system has nothing to do with the regular control of the car, as handled by the driver when running on the road, but simply controls the auxiliary pump driving and oiling, supplying steam driven water and air pumps and directing the hand pump oil supply.

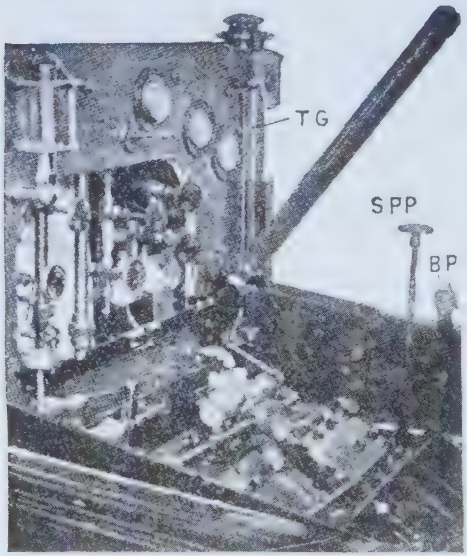


FIG. 396.—The Lane System, engine placing and control, footboards and auxiliary control cover removed. The illustration shows the inclined engine cylinders, the independent steam water pump and the hand water pump, last resort for supplying the boiler water. The hand cylinder and steam pump oiler, a glass cup with a hand force pump is shown at the upper left of the front board real face. Next to the right is the dial indicator which shows the boiler water level. The next dial shows the air pressure in the gasoline tank, and the third dial is the steam gauge. The glass tube at the right, TG, shows the water level in the water tank. The auxiliary control cover, when removed, discloses 8 handles, top left handle opens the hand oil pump to the independent steam water and air pump steam cylinders, the top row middle handle works the compressed air valve to either send air to the gasoline tank or to the tire inflating tube, or to open air if tire inflating hose be removed. The right hand top valve is the steam pump steam admission. The left handle in the middle row opens the oil lead from the hand pump to the engine steam chest. The middle handle controls the stop valve in the line from the engine driven air pump to the gasoline tank. The right handle in the low line opens steam to the steam water pump. The fusible plug screw T-handle is seen at the left of the front board auxiliary control opening. The metal wheel just below works the stop valve between the fusible plug and the steam boiler. SPP is a plunger pedal which is depressed to change the engine from compound to simple. BP is the ordinary brake pedal.

The emergency water and air pumping, when required, is done by independent steam pumps the air pump being available for both tank pressure and tire inflating, so that the driver is relieved from all pump work.

Cycle of Operation.—With steam up and the car running, the feed pump on the engine forces water to the boiler.

The water passes, first through the feed water heater located in the top of the condenser, where it absorbs heat from the exhaust steam, before entering the boiler preheating coils.

In passing through the preheater coils, the temperature of the water is considerably raised, and it is discharged from these coils into the *separator,* as water and steam.

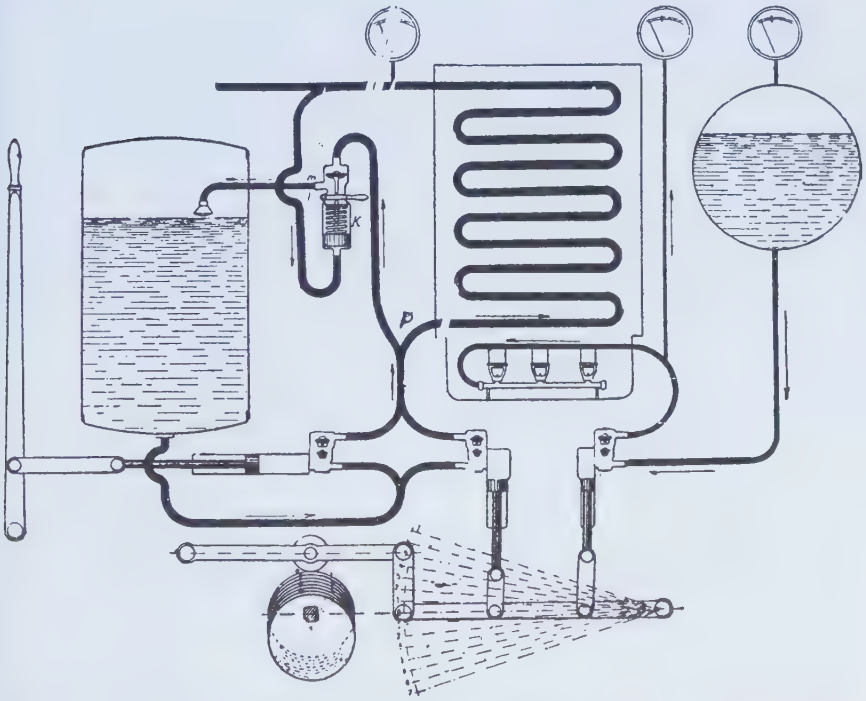


FIG. 397.—The Serpollet Water and Fuel Feed System. The method of hanging the stepped cam controlling the pump stroke may be here understood.

The water is led from the separator to the bottom of the tubular shell and the steam to the top.

Saturated steam is taken from the top of the shell, whence it is delivered to the engine in a slightly superheated state.

The steam after working expansively in the high pressure cylinder of the engine approaching a state of saturation, is ex-

hausted into a larger or low pressure cylinder where it is again expanded and finally exhausted into the condenser; here it is practically all condensed under ordinary conditions and the water returned to the tank to again begin the cycle as just described.

When the engine is heavily loaded as in ascending steep hills, the condenser may be overtaxed and only condense a portion of the steam. This together with other losses, such as leaks from the stuffing boxes, etc., have to be made up by replenishing the water supply in the tank.

The efficiency of the condenser depends, largely on the temperature of the atmosphere. This is clearly indicated by the difference in its operation in winter and summer.

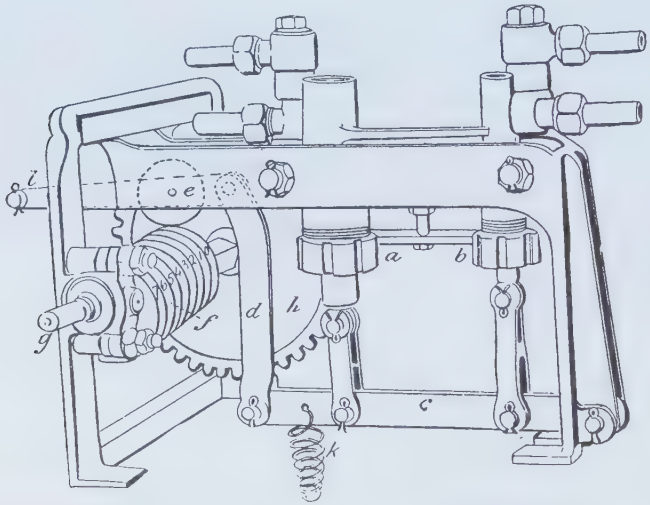


FIG. 398.—Serpollet's Fuel and Water Pumps. The water pump, *a*, and the fuel pump, *b*, are operated from the lever. *c*. This is given an up-and-down movement by the link, *d*, whose stroke is varied by the stepped cam, *f*, on which bears the roller, *e*, on the rod pivoted at *i*. The rotary movement of the cam shaft, *g*, is imparted by the spur wheel, *h*.

Flash Steam Generation: The Serpollet System.—The flash method of producing steam, was introduced by Serpollet in 1889. He invented an instantaneous generator which is described in the chapter on boilers.

The successful operation of a flash generator depends largely on the design of proper automatic devices and connections for regulating the supply of feed water and fuel. The office of these automatics is to so control the generation of steam that a supply, varying to meet the engine demands, may be had at a certain predetermined pressure and degree of superheat.

It is possible to maintain the feed at the proper rate and quantity by automatic pressure regulators, such as are used in connection with steam carriage burners, or else by some system of uniform regulation for fuel and water pumps.

The latter theory was adopted in the Serpollet system being worked out by Gardener.

As shown in the diagram, the fuel is fed to the burner, and the water to the boiler, through pumps, both of which are operated from the same shaft. The fuel pump is smaller than the water pump and its stroke is also shorter, as is obviously necessary. This is accomplished by the use

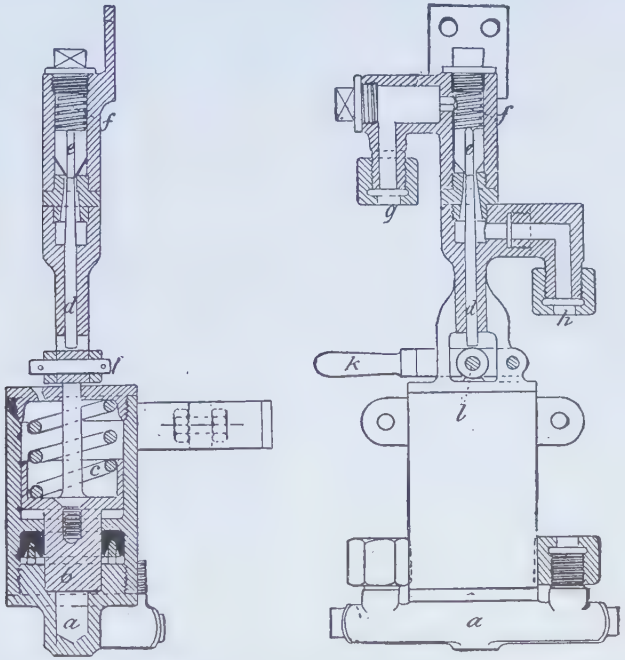
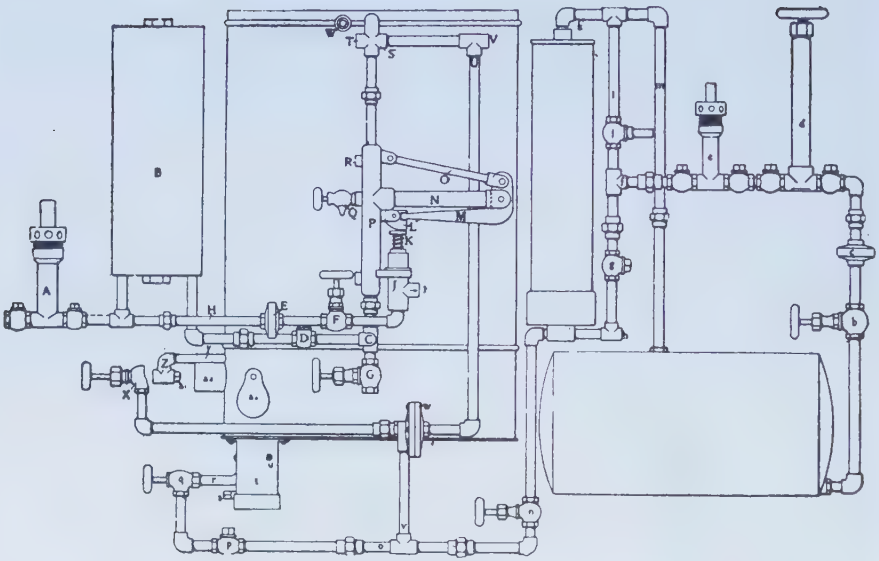


FIG. 399.—The "Safety Valve," or Automatic By-Pass Regulator of the Serpollet Boiler Feed System. The steam, admitted through the tube, *a*, after it has reached a certain pressure, opens the valve, *b*, compressing the spring, *c*. By this action the rod, *d*, forces up the valve, *e*, and the spring, *f*, thus enabling the water from the pump to pass from the pipe, *g*, through the pipe, *h*, to the water tank.

of a stepped cam, consisting of a row of eccentric discs, of varying eccentricity, which, placed upon the rotating shaft, may be slid in either direction, thus varying the lift. By shifting the cam inward toward the driving spur the strokes of both oil and water pumps may be varied from zero to maximum; the cam surface being efficient in giving a greater or shorter inward stroke, and in permitting an outward stroke of equal length under stress of the spiral spring attached below the pump operating lever.



A-Power Feed Water Pump
B-Feed Water Heater
C-Connection for Boiler Feed, Water Regulator and Bottom Blow Down
D-Boiler Feed Check Valve
E-Water Regulator Gauze Strainer
F-Globe Valve
G-Boiler Blow Down
H By-pass Line to Water Regulator Valve
I-Water Regulator Valve By-pass Connection
J-Water Regulator Valve
K-Water Regulator Valve Cam
L-Water Regulator Valve Cam
M-Water Regulator Lever
N-Water Regulator Expansion Tube
O-Water Regulator Lever Brace
P-Water Regulator Water Column
Q-Water Regulator Pet Cock
R-Top Connection for Gauge Glass if Desired
S-Water Regulator Water Column Connection
T-Connection for Steam Gauge, Pumps, Etc.
U-Steam line to Fuel Regulator
V-Connection for Pop Safety Valve, Etc.
W-Steam Connection for Engine

a-Main Fuel Tank
b-Globe Valve
c-Gauze Strainer
d-Hand Fuel Pump
e-Power Fuel Pump
f-Connection to Automatic Fuel Feed
g-Check Valve
h-Connection to Fuel Gauge
i-Automatic Fuel Feed
j-By-pass Valve of Automatic Fuel Feed
k-Return Line of Leakage by Piston
l-Fuel By-pass Line
m-Return Line to Tank of k and i
n-Globe Valve
o-Branch Fuel Line to Pilot
p-Check Valve with Check Removed and Sponge in its place for a Dirt Strainer
q-Pilot Valve
r-Pilot Vaporizer
s-Pilot Nozzle
t-Pilot Box
u-Screw for Holding Pilot Vaporizer Straight
v-Fuel Line to Main Burner
w-Automatic Fuel Regulator
x-Main Burner Valve
y-Main Burner Vaporizer
z-Main Burner Elbow
a1-Main Burner Nozzle
a2-Main Burner Mixing Tube
a3-Slide Over Hole for Observing Fire

FIG. 400.—The Ofeldt system of automatic fuel and water regulation as applied to the Ofeldt boiler. The operation of the water regulator is explained under Fig. 374. The automatic fuel feed i, consists of a brass tube four inches in diameter by eighteen to thirty-six inches long, capped on one end and plugged on the other. Inside this tube is a piston and a spiral spring, the latter being the whole length of the tube. A safety valve is attached to the by-pass line, which can be set to carry whatever pressure is desired. A connection is also made to permit whatever fuel leaks by the piston to return to the tank. A hand fuel pump d, is provided for use when starting the burner. The operation is as follows: Fuel is forced by a fuel pump e, on crosshead of engine or else where through connection f to the cylinder and against the piston, which in turn compresses the spring and the latter gives the pressure to the fuel. The fuel is forced to the burner through the line containing valve n. A safety valve j, can be adjusted to carry any pressure desired; i, is the overflow connection to tank.

These operations may be readily understood by a study of Fig. 397, which is sketched from the actual machine.

The liquid fuel and the water, being thus varied in the amounts given forth by the pumps, are forced, the one into the vaporizing tube, passing over the burner, the other into the flattened and nested tubes of the generator. By this means the heat is increased in ratio with the quantity of water injected, and the working pressure may be regulated to any desired limit. When, however, the pressure has arisen above a certain fixed point—it is generally fixed at about 355 pounds per square inch—it is able to open the spring safety valve, k, shown attached to the steam pipe, fig. 399, thus also opening the by pass, m, so that the water from the feed pump is thrown back into the tank.

The water from the pump may be forced through the spring valve, instead of into the generator, by the closing of a check valve at *P*, under steam pressure.

The connections may be readily understood from the diagram, which also shows a hand operated pump for making the initial injection of water into the generator tubes previous to starting the engine.

The construction and operation of the automatic by pass regulator, or "safety valve," may be understood from Fig. 399.

Strictly speaking, a flash generator needs no safety valve, but its operation demands some method of preventing flooding when the pressure is high enough.

The White System.—The method of regulating the supply of water and fuel to the steam generator of the White steamer, presents an inter-relationship of water, gasoline and steam that is highly interesting, exceedingly unique, and, as demonstrated daily by the cars, is most satisfactory. Broadly speaking, the operation of the system, depends on three factors:

1. Water;
2. Gasoline;
3. Steam.

The water carried in the tank must be delivered in proper quantities to the generator, where it is flashed into steam.

Gasoline must be delivered in the proper quantities to the burner so that the correct heat is maintained to generate and superheat the steam.

The steam must be supplied in a highly superheated state, in requisite quantities to meet the varying engine demands.

Since a generator, or flash boiler as it is sometimes called, carries no reserve volume of water or steam, the intensity of the fire and the quantity of feed water supplied, must be continually varied to correspond with operative conditions.

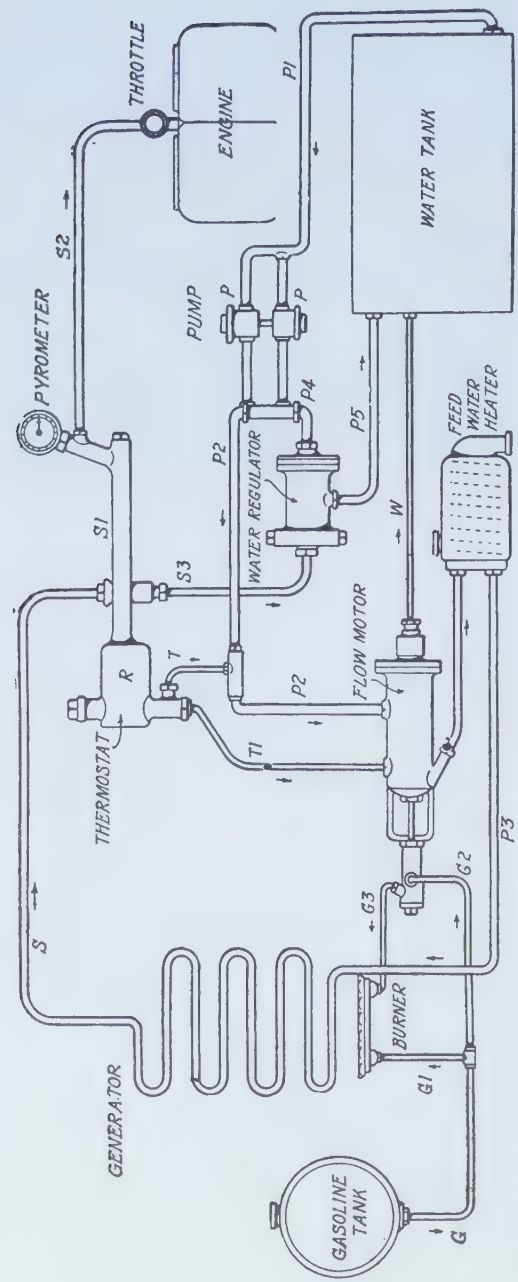


FIG. 401.—Diagram illustrating the White system of flash steam generation, and automatic control of the steam supply, pressure and temperature. Briefly, the operation of the system is as follows: When the engine is running: 1, It operates the feed water pumps, 2, the *water regulator* either by passes back to the tank all the feed water, or allows it to flow towards the generator according as the steam pressure is above or below 550 pounds, 3, the feed water from the pumps flows to: a, the *flow motor* and b, the *thermostat*, 4, the flow motor by-passes its water to the tank when it exceeds the capacity of the generator, and 5, the thermostat produces the necessary variations in the ratio between the fuel supply to the burner and the feed water supply to the generator.

In this system, 1, the steam pressure is made to control the supply of water delivered to the generator, 2, the water pressure controls the gasoline feed, and 3, the steam temperature has bearing on the water supply. Hence, there is an inseparable interrelationship among the gasoline, water and steam.

The system is diagrammatically illustrated in Fig. 401. In the water system, the water must go from the water tank to the generator; it is drawn from the tank by two positively driven pumps P on the engine through pipe P1. From each pump it follows the piping P2 to the flow motor, whose workings will be considered later; thence to the feed water heater, which is simply a coil of pipe at the engine to heat the water before it goes through pipe P3 to the generator.

The pumps P are constantly working when the engine is running, always pumping the same amount of water per minute, at the same engine speed; however, it is evident that sometimes more steam is needed than at others at the same engine speed, and consequently more water will be needed.

The first device for regulating the flow of water is the *water regulator* into which the water flows by pipe P4. Its entrance to the regulator is governed by a valve, which only opens when the steam pressure gets above 600 pounds.

This opening is accomplished by steam pressure through the pipe S3, acting on a diaphragm which opens the valve, letting the water enter the regulator and escape through the pipe P5 back to the water tank, so that when there is 600 pounds pressure, which is the working figure, the water delivered by the pumps P *does not follow* the course to pipe P2 to the generator, *but is by-passed* through pipes P4 and P5 to the water tank.

With the water delivered to the generator, gasoline must be delivered also in order to have heat to generate steam. The gasoline is carried under pressure in the tank at the rear of the chassis, and starts on its trip to the burner through pipe G, the first branch G1 goes to the pilot light which must be kept burning all the time the car is running.

This pilot light is a small flame whose heat does not enter into changing the water into steam, but serves solely to light the gasoline vapor in the burner, as it must be realized the burner flame is out one minute and on the next, according to the amount of steam required; the automatics of the system shut off and turn on the burner according to the demand, but the pilot light always burns to serve as the match for ignition.

The gasoline, which goes to generate steam, follows pipe G2, into the pointed end of the *flow motor,* where its flow is regulated by a valve, opened and closed according to the water pressure, and finally reaches the burner through the pipe G3. Some gasoline controlling valves are not shown in the diagram, the object of this diagram being merely to show the elements of the system.

Having the water and gasoline at the generator, steam is the product and its course to the engine is next in order. It follows the main pipe S, which, before reaching the engine, has an en-

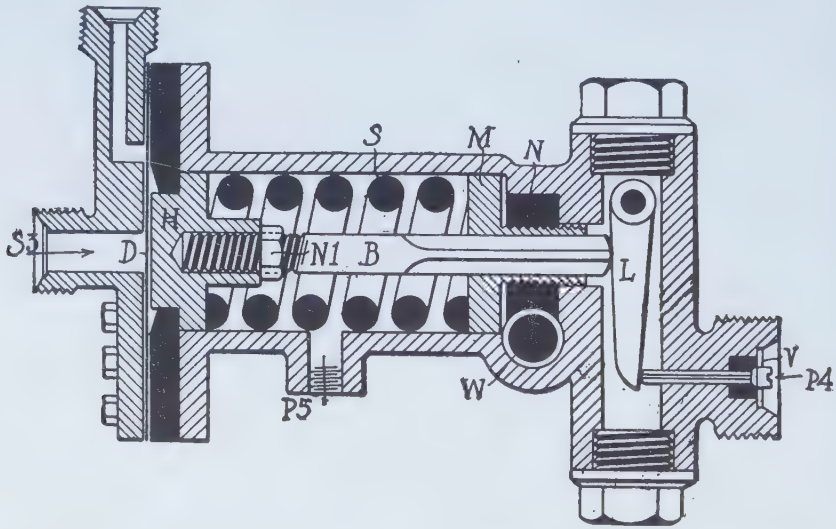


FIG. 402.—The White water regulator. This consists of a diaphragm valve operated by the steam pressure in the generator.

larged section S1 which contains the copper rod of the *thermostat,* and then reaches the engine through the continuation pipe S2.

There is a branch S3 for conveying steam pressure to the water regulator.

The *pyrometer* indicates the temperature of the steam.

In brief, the action of the thermostat is to govern an additional supply of water to the generator. When the temperature of the steam gets too high, it means more water is needed in the gen-

erator, and the thermostat delivers this extra water supply as follows: The higher temperature of the steam expands, or lengthens a rod, which through a rocker arm opens a valve, allowing water from the main supply pipe to flow through the pipe T and thence through pipe T1 into the *flow motor.*

As soon as the temperature of the steam drops to normal, the thermostat, through the copper rod, automatically shuts off this water supply. There is a further control on the water by the flow motor, which, at a certain time, by-passes through the pipe W water to the tank.

The exact operation and construction of the water regulator, the thermostat, and the flow motor follow.

The Water Regulator.—This device is shown in fig. 402, and has as its most essential feature a triple diaphragm D against one side of which the steam from the engine bears through the pipe S3. On the other side of the diaphragm is a metal member H, adjustably secured to the shaft B, and which member at its opposite end bears up against the lever L, the lower end of which contacts with the stem of the valve V. This valve V regulates the water entrance P4 from the pumps, so that when the valve opens water enters and escapes by way of pipe P5 to the water tank. The coil spring S normally holds the piece H against the diaphragm so that the valve V closes. However, when the steam pressure through S3 exceeds a certain figure, the diaphragm is forced to the right compressing the spring S and opening the valve V, allowing the water to flow as mentioned. As indicated in fig. 401 the water is by-passed to the water tank.

The Flow Motor.—As shown in fig. 403, this consists of three parts, 1, the right section W in which the water control is adjusted, 2, the small end portion G at the left which controls the gasoline flow to the burner, and 3, the connective portion C.

Water enters direct from the pumps through the opening WE, passing out through WD. Its control of the water is by the piston P which when moved leftward by the water pressure uncovers the groove G, thus allowing the water to pass it and escape through the connection WD. This piston P is in rigid connection with the gasoline controlling valve GV in the left compartment of

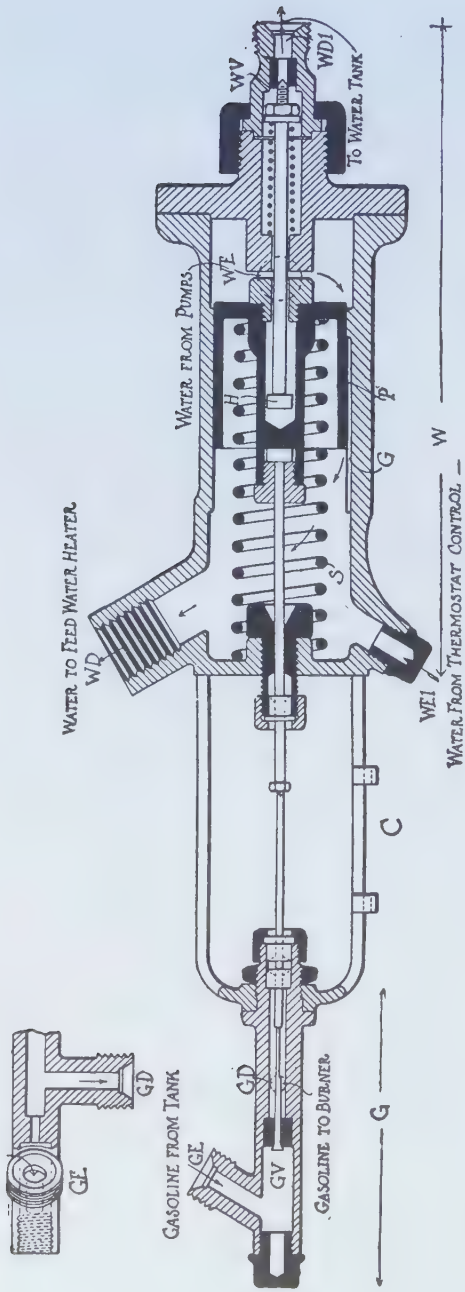


FIG. 403.—The White flow motor. This is a device by which, when there is any flow of water through it, the rate of flow of water is made to govern the rate of flow of fuel. The action of the flow motor depends on the amount of water passing through it and not on the pressure.

the flow motor, so that the valve GV also moves leftward permitting gasoline, which enters from the gasoline tank through the opening GE to escape to the burner through another opening GD.

The faster the engine runs the greater the volume of water delivered by the pumps and the greater the water pressure against the piston P the further will it be moved leftward against the spring S, the more water will pass it, and proportionately the more gasoline will go to the burner.

When the piston P has traveled leftward a certain distance it comes in contact with the end H, which is on the stem of the valve WV, and a further leftward movement of the piston P opens this water valve, which allows water to escape through the

by-pass valve WD1 and thence to the water tank. This by-pass valve opens only when too much water is being pumped, and lets a portion go back to the tank. The entrance WE1 is for water admitted from the thermostat control.

The Thermostat.—This device is a regulator, acted on by the temperature of the steam after it leaves the generator, but before it reaches the engine. The operation of the thermostat is shown in Fig. 404. Steam enters through SE from the generator and de-

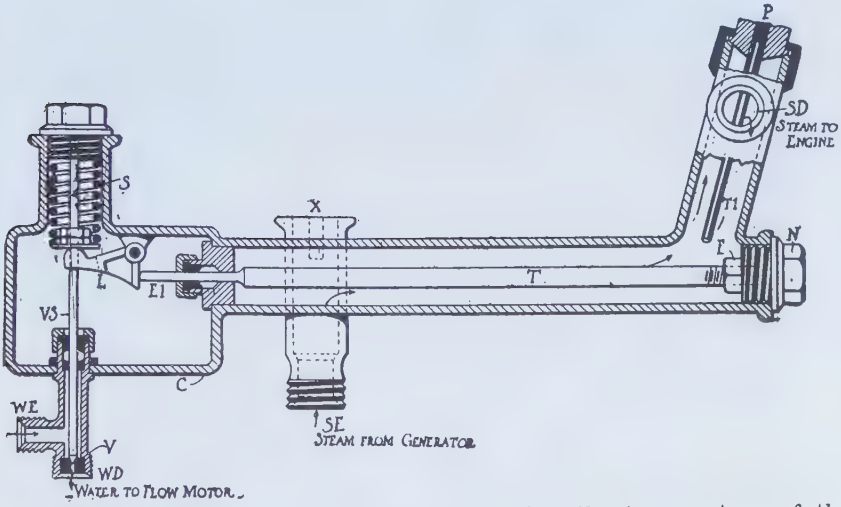


FIG. 404.—The White thermostat for regulating the temperature of the steam. In connection with the thermostat, is a pyrometer in which the temperature of the steam is shown on a gauge.

parts through opening SD to the engine. In its passage it contacts with a copper rod T anchored rigidly at one end E in the casing, and at the end E1 bearing upon a lever L which bears upon a collar on the valve stem VS. The high temperature of the steam lengthens the rod T which through the lever L, opens the valve allowing water to flow to the flow motor and thence to the generator, thus reducing the steam temperature. The flow motor lets gasoline go to the burner in proportion to the water sent to the generator, and if too much water is being pumped, it returns a portion of the water direct to the water tank.

To Start the White Car.—After the water and fuel tanks are filled, air pumped to 30 pounds by the hand air pump, *and the generator pumped full of water,* the sub-burner V, fig. 405, is then lighted.

The sub-burner, will in about five minutes, sufficiently heat the vaporizer N to vaporize the fuel for the main burner.

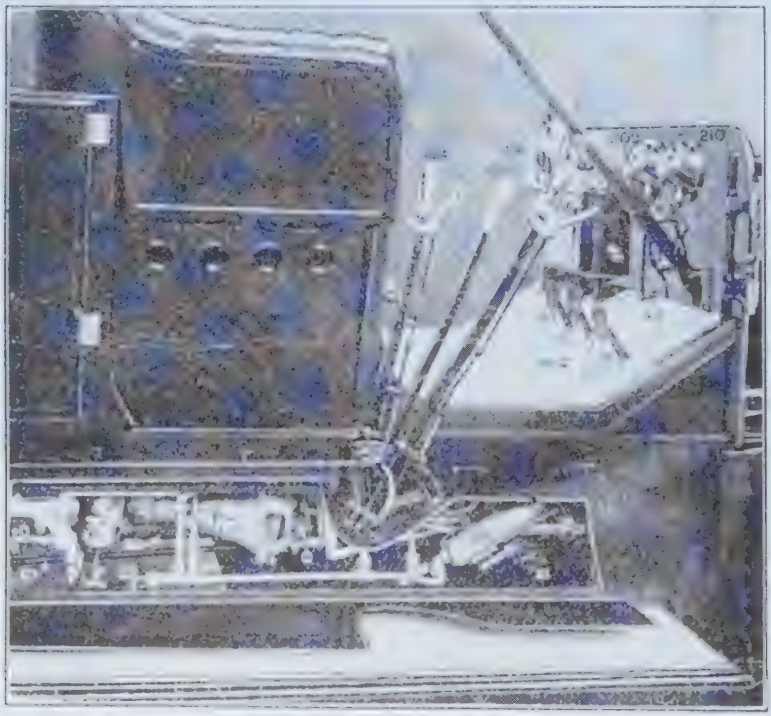


FIG. 405.—Side view of dash of White car. The parts shown are as follows: 42, pyrometer; 43, relief cock lever; 82, cut off pedal adjusting pin; 91, cut off pedal; 93, simpling valve pedal; 94, air pump valve pedal; 95, brake pedal; 103, emergency gear lever; 104, reverse lever; 105, brake lever; 108, cylinder oiler pump; 109, crank case oiler pump; 111, blow off valve; 112, driving shaft; 113, emergency gear rod; 120, flow motor; 209, air and vaporizer gauge; 210, steam gauge; D, main sub-burner valve; F, sub-burner adjusting valve; G, warming up valve; HA, pipe connecting valve G with vaporizer N; J, main burner valve; O, vaporizer nozzle; V, sub-burner casing; W, sub-burner casing door.

To start the main burner, the warming up valve G is slightly opened. This allows the fuel to flow from the main fuel line into the vaporizer N, through pipe HA, without passing through any regulator. Should the vaporizer not be thoroughly heated a

few drops of raw fuel may drip from the vaporizer nozzle O. If this drop be continuous, valve G should be closed to allow the vaporizer to become hotter.

It is advisable in starting to open and close valve G intermittently four or five times, the interval of opening being about two seconds. By this means any sudden rush of fuel is avoided before the vaporizer gets thoroughly heated.

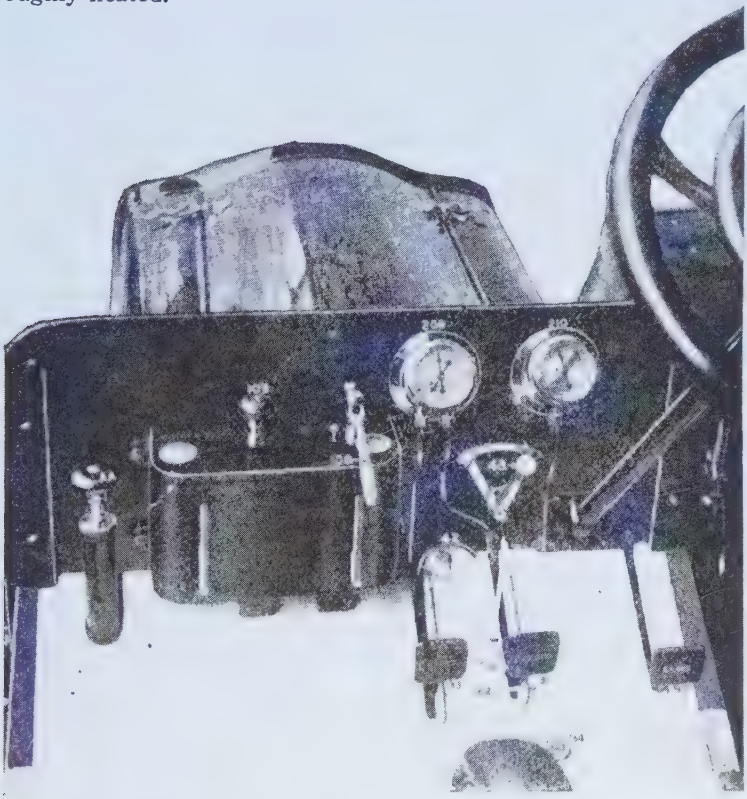


FIG. 406.—The White dash as seen from the driver's seat. The operating devices shown in the cut are as follows: AA, hand air pump; 42, pyrometer; 43, relief cock lever; 82, cut off pedal adjusting pin; 91, cut off pedal; 93, simpling valve pedal; 94, air pump valve pedal; 95, brake pedal; 108, cylinder oiler pump; 109, crank case oiler pump; 209, air and vaporizer pressure gauge; 210, steam gauge. The small wheel concentric with the steering wheel is the throttle.

With the main fire satisfactorily started, valve G may be left open about one-quarter turn. The safety valve should now be closely watched. This is important, as the steam pressure runs up very quickly and any inattention when the fire is first turned

on may result in excessive pressure and cause the safety valve to open. As soon as the pressure reaches 300 pounds, the surplus water collected in the pipe should be blown off through the blow off valve 111 fig. 405, being careful to close this valve as soon as steam appears. The steam pressure is then allowed to again reach 300 pounds. The warming up valve G, is now adjusted so that there is not over twenty pounds showing on the vaporizer pressure gauge 209.

With gear lever 103 in the central or neutral position, so that the engine may run without moving the car, and with cylinder relief cocks opened by lever 43, the engine is started by first pushing the starting pedal 93 all the way forward and then opening slightly the throttle.

The water should be worked out of the engine easily and carefully, by cautious handling of the throttle and by working the reverse lever back and forth from forward to reverse position until the engine is warmed up and will turn over freely. Valve G should now be closed and valve J opened. In warming up the engine, just enough steam should be admitted to the cylinders to keep the engine moving slowly *until all the water is out* when it will run smoothly. Until all the water is out, the engine will run jerkily on account of this water filling the clearance spaces in passing the dead centres, hence, the engine should not be forced by too much throttle opening, but the water should be worked out gradually.

When engine runs smoothly, the relief cocks may be closed by throwing lever 43 over to the right hand position. To get the cylinders thoroughly heated, the foot is transferred from the starting pedal to the cut off pedal 91 and the latter pressed forward so that steam will be admitted for full stroke. The engine should be run thus for about one-half minute and then for two or three minutes with cut off pedal in its normal position, allowing the steam to work expansively.

The air presure is now pumped to 50 pounds, and the subburner adjusted to this pressure after which the car may be started.

Summary.—The operation of the White system may be stated briefly as follows:

1. When the engine is running, it operates the feed water pumps.

2. The *water regulator* either by-passes back to the tank all of the water delivered by the pumps, when the steam pressure *exceeds* 550 pounds, or it allows all of the water to flow toward the generator when the steam pressure is *less than* 550 pounds.

That is to say, the water supply is controlled by an "all on" or "all off" action—the required variations being due to changes, automatically brought about in the frequency and durations of these "all on" periods.

3. The feed water from the pumps flows through two branches:

   a. The flow motor branch;

   b. The thermostat branch.

The water going through the flow motor branch moves a piston in the flow motor which in turn, proportionately opens the fuel valve. It also opens the by-pass valve in the flow motor, when the rate of water flow into the flow motor exceeds the capacity of the generator, and by-passes the excess water.

The water going through the thermostat branch, is increased or decreased in amount by the action of the thermostat in opening or closing the water valve of the thermostat. This action produces the necessary variations in the ratio between the fuel supply to the burner and feed water supply to the generator.

The practical result of the automatic actions of the different members of the system is to maintain the steam at a practically uniform high pressure with a considerable degree of superheat under all working conditions.

Flash Steam Data.—The following results were obtained in a series of tests made on the steam plant of the White steamer. For the purpose of testing, the engine was mounted on the frame of a car in the same manner as in the completed motor car, which was, however, supported by solid posts instead of by wheels. The main shaft of the engine was connected to an Alden Prony brake and all the horse power calculations were for *brake* horse power, it being deemed not advisable to use the indicator on account of the small size and high speed of the engine.

During certain of the various tests the boiler pressure averaged 595 pounds, the steam chest pressure varied with the load from 152 pounds to 427 pounds, averaging 303 pounds. The temperature of the steam near the boiler average 783° Fahr., and that in the steam chest 757°. This indicates that the steam leaving the boiler was superheated nearly 300°, that entering the steam chest about 340°, and that exhausted about 28°, so that the steam in its entire passage through the engine remained in a superheated condition.

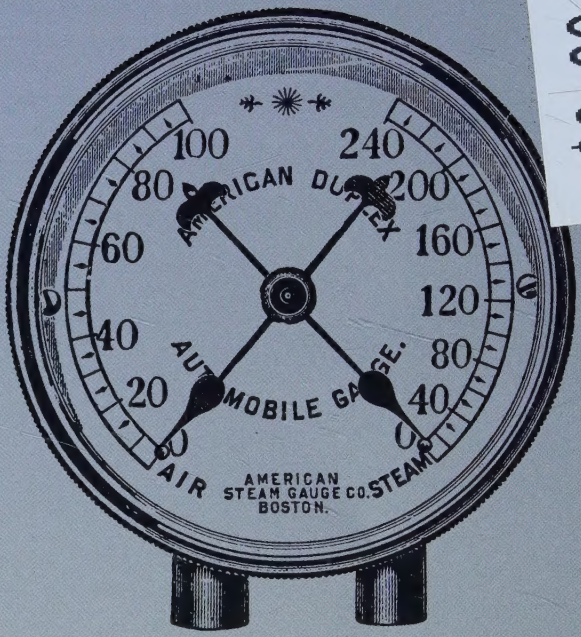
The actual evaporation from feed water at 78° to steam with the pressure and temperature as shown averaged 10.34 pounds of water per pound of gasoline. The equivalent evaporation "from and at 212°" per square foot of heating surface per hour was 13 pounds for the highest result.

The engine developed a horse power on the brake at its highest load with a consumption of 11.96 pounds of feed water per hour. This remarkably small consumption of feed water shows the value of superheating the steam, it being well known in steam engineering that the saving in feed water due to superheating is a little over one per cent. for each 10° of superheat.

The important facts brought out by the tests are: 1, the feed water consumption of a small compound non-condensing engine using highly superheated steam is very small; 2, when a flash boiler is used, the required amount of heating surface to run the engine is approximately one square foot per brake horse power.

The following table shows the results of some of Prof. Carpenter's tests:

No. of Test.	Revolutions per Minute.	Net Brake Load Lbs.	Brake Horse Power.	Total Lbs.		Water per Brake Horse Power per Hour Lbs.	B. T. U. Above 212° to Engine.				Actual Evaporation per Pound Gasoline.	Actual Evaporation per Square Foot of Heating Surface per Hour.
				Water per Hour Lbs.	Gasoline per Hour Lbs.		Per Lb. of Steam.			B. T. U. per Brake Horse Power per Minute.		
							Saturated Part.	Superheated Part.	Total.			
14	850	72	25.50	320.0	31.125	12.55	1034	198	1232	257	10.30	6.98
15	850	85	30.1	370.0	31.125	12.29	1036	196	1234	252	10.42	8.07
15a	850	85	30.1	370.0	35.5	12.29	1038	196	1234	252	10.42	8.07
15b	850	85	30 1	371.5	35.5	12.30	1035	202	1237	253	10.45	8.11
16	850	96	34.0	408.8	39.25	12.05	1036	200	1236	246	10.40	8.87
17	850	115	40.7	488.0	48.0	11.96	1037	197	1224	244	10.15	10.7
								av. =	1228	av.	10.34	



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